Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 258 DECEMBER, 1954 No. 6

THE TRAVELING WAVE TUBE—A RECORD OF ITS EARLY HISTORY

BY

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INTRODUCTION

The traveling wave-electron beam interaction principle featured in the modern traveling wave amplifier is one of the oldest of the mechanisms which have found extensive use in microwave tubes. Electron tubes employing this principle amplify by virtue of an interaction (continuous in time and extended in space) between an electromagnetic wave and an electron stream moving along together at nearly the same velocity. Usually, the wave is propagated by a structure designed to slow the wave velocity considerably; the helix and the loaded wave guide have been found suitable for this purpose.

Studies of this energy exchange method began both theoretically and experimentally two decades before World War II. As early as 1940, the first ideas for applying this radio frequency amplification technique in the device now known as the helix traveling wave amplifier had been demonstrated by laboratory experiments. Then, in the space of seven years, a firm basis was established for today's success of the traveling wave tube as a broad band low noise amplifier, power amplifier, tunable amplifier or oscillator, and microwave oscilloscope tube.

THE MAGNETRON OSCILLATOR AND THE TRAVELING WAVE INTERACTION PRINCIPLE

In addition to the cyclotron type of oscillation discovered in the split-anode magnetron by A. Zacek (1) [2] of Prague in 1924, and in addition to the negative resistance type of oscillation predicted in a theoretical study by E. Habann (2) of Jena in the same year, K. Pos-

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

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thumus (3) of Holland first recorded in 1935 the observation of a third type of oscillation in the multi-anode magnetron. He termed this the rotating field oscillation; it was later studied as a traveling wave oscillation by J. C. Slater, D. R. Hartree, and E. C. Stoner, and by others investigating the cavity resonator magnetron during World War II (4, 5). This third type of oscillation, studied for the first time both theoretically and experimentally in two- and in four-segment magnetron oscillators by Posthumus, has proven to be the most useful mode of operation of the magnetron; consequently, this type of operation is employed in all modern cavity resonator magnetron oscillators.

Posthumus correctly interpreted the electronic nature of the oscillation in his four-segment tube as due to an interaction mechanism between the electrons and the tangential component of a rotating field, this traveling field having a velocity nearly equal to the average velocity of the electrons. During his experiments, he observed that the new mode of operation of the magnetron oscillator was one in which the preferred frequency of oscillation is determined by the anode circuit, by the strength of the magnetic field, and by the anode potential.

Posthumus visualized a magnetron oscillator having a multiplicity of pairs of anode plates coupled to Lecher wire circuits. When he considered that there exists in the interaction region a simple (non-rotating) alternating field with a number of poles equal to the number of anode plates, he noted that such a field could always be resolved into two traveling multi-pole fields having equal and opposite velocities. The traveling wave moving in the direction opposite that of the electrons was neglected as having no significant effect, and consideration was given only to the wave moving in the same direction as, and with nearly the same velocity as, the electron stream. The inverse wave was considered negligible because its field produces a small alternating acceleration and deceleration of the electrons at a rate such that its effect on the electrons is averaged out, only the primary traveling wave, that is, the synchronous wave, having an appreciable effect on the electron trajectories. It is due to this synchronous relation of the primary traveling wave and the rotating multi-polar electron cloud that the potential energy of the cathode-anode electric field is converted to a growing radio frequency wave in the oscillator circuit, and that oscillations in the circuit are maintained at a level determined by the effectiveness of the electronic energy interchange and by electronic and circuit losses.

OTHER EARLY TRAVELING WAVE ELECTRON STREAM INTERACTION DEVICES

The subsequent history of the magnetron oscillator, particularly of its rapid development after the innovations introduced in England by H. A. H. Boot, J. T. Randall, and J. Sayers, has been discussed in detail by many authors (6, 7, 8, 9). In theory and in practice, it is the most complex of a family of electron tubes adapted to operation in the micro-

wave region. It has been exploited mostly as an oscillator, but has been used also as an amplifier; it has been built mostly in a form having circular symmetry, but also in planar forms. Its theory of operation is complex because the problem of predicting its electron trajectories is one of a two-dimensional nature, rather than being a one-dimensional problem, as is true in the usual forms of the lineal traveling wave amplifier and charged particle accelerator. This latter pair of microwave-electronic devices is generically of one group in the sense that such tubes both involve traveling wave interaction between a lineal electron beam and the synchronous component of a radio frequency field traveling along a lineal wave propagation structure. The synchronous wave may be an independent running wave on a non-resonant interaction circuit, or it may be one of the oppositely running wave components of the standing wave pattern characteristic of a resonant interaction circuit. The same duo is also generically related to the magnetron, in that characteristic of all three devices is a cycle of events in which electrons become bunched and move along with a traveling electromagnetic wave of nearly equal speed, so that the traveling wave is continuously amplified at the expense of the kinetic energy of the electron stream, or *vice versa* (as in the case of the lineal charged particle accelerator).

Although the description of the device contains no reference to the possibility that useful amplified energy might be extracted directly from the wave propagation element of the tube, A. V. Haeff (10) described in October of 1933 electron beam deflection tubes of the detector and oscillograph types in which there are found some features common to the modern helix traveling wave amplifier. One of these tubes, illustrated in Fig. 1, is based on the following principle: if the speed of the

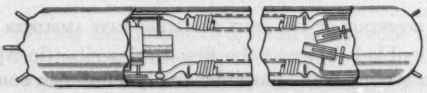

FIG. 1. Haeff's traveling wave detector tube.

electrons is made about equal to the velocity of electromagnetic waves traveling along two helical electrodes, then, electrons moving in synchronism with the crests of the waves are subjected to a deflecting force acting continuously in the same sense so long as the electron beam travels between the helices. Haeff considered this device useful either as a standing or traveling wave deflection tube. If standing waves were employed, the component of the standing wave traveling in the direction opposite to electron beam flow would produce no significant effect. On the other hand, the component of a running or standing wave traveling in the same sense and with the same speed as the electron beam would cumulatively deflect the beam. The useful signal extracted from this

tube is obtained by the deflection action of the two helices in forcing the electron beam to be collected by one or the other of two conductive electrodes. In another form of the tube, an oscilloscope screen is used for visual observation of the presence of a radio frequency signal on the propagation structure. In a further form of the device, a detector system was envisioned in which a hollow electron beam surrounds the helix and a detected output can be derived from concentric anode elements. Though the tubes described by Haeff at this time contain several of the features common to modern traveling wave amplifiers which do, indeed, utilize the true traveling wave mechanism of amplification, there is no hint in their description that these tubes operate according to that principle, or that useful amplified radio frequency energy can be derived from the helices.

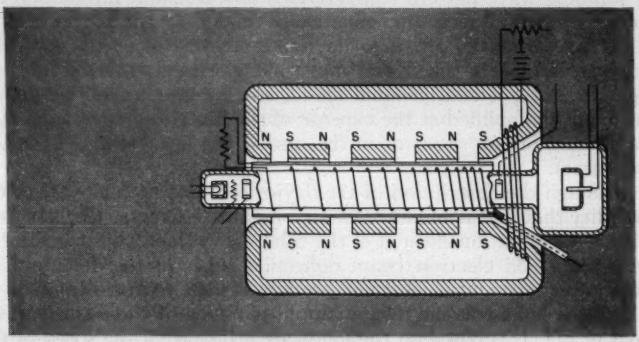

FIG. 2. Lindenblad's traveling wave amplifier.

INVENTION OF THE HELIX TRAVELING WAVE AMPLIFIER

N. E. Lindenblad (11) was the first to describe (in May of 1940) a type of helix traveling wave amplifier really similar in construction and in principle to the modern helix traveling wave amplifier. Here was first clearly set down the idea that a traveling radio frequency wave could produce an amplified signal at the output end of a matched helix, generated by synchronous interaction between an electron beam and radio frequency currents in the helix. Lindenblad described a vacuum tube utilizing a lineal electron beam and using the true traveling wave amplification mechanism in which the average speed of the electron beam is made nearly equal to the velocity of propagation along the axis of the tube of the growing radio frequency wave induced in the helical conductor by electron bunches appearing in the electron stream. In his concept, induced radio frequency currents in the helical conductor move in the same axial direction as the electron beam and are continuously and cumulatively produced by the traveling wave interaction

mechanism. Lindenblad also observed the desirability of tapering the pitch of the helix as the electron beam progresses down the tube, this method allowing for the loss in velocity of the electron beam as its energy is progressively converted into radio frequency energy. In a form of the tube tested prior to May of 1940, shown schematically in Fig. 2, Lindenblad found it possible to produce useful amplification over a 30-mc. band at a carrier frequency of 390-mc. with only a 3-db. variation over the band. It is understood that this tube was developed in connection with relay transmitter research performed at Rocky Point, Long Island, New York, in which inductive coupling cavity resonator tubes were being utilized as oscillators and amplifiers. Considering the general need for improved broad band high frequency amplifiers, Lindenblad modified one of these tubes, extending the vacuum envelope and replacing the cavity resonator with an external solenoidal transmission line of such pitch that the axial velocity component of the wave traveling on the line could be made about equal to the axial velocity of the electron beam, the transmission line being matched so as to be free of standing waves. The line was wound directly around the outside of

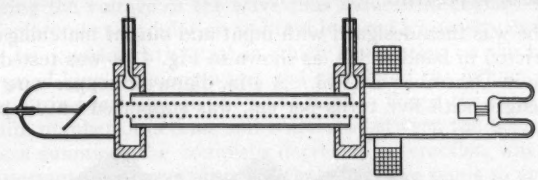

FIG. 3. Kompfner's first amplifier, April, 1943.

the cylindrical glass envelope and the tube was placed on the axis of a large coil providing the necessary focusing magnetic field. The tube was excited by placing the output of a small acorn tube oscillator on a control grid, or by the now more usual step of coupling the signal to be amplified to the input end of the helix adjacent the cathode. This test represented the first known demonstration of the practical use of the traveling wave principle in an amplifier characterized by the inclusion of all of the significant features of the modern helix traveling wave amplifier.

WORLD WAR II RESEARCH IN ENGLAND ON THE TRAVELING WAVE AMPLIFIER

The next serious research activity in this field began in England at Birmingham University in 1943 and was carried on subsequent to 1944 at the Clarendon Laboratory of Oxford University. In this research, R. Kompfner (12) has reported to have realized late in 1942, in considering some of the characteristics inherent in then available microwave tubes, that the basic growing wave principle of the magnetron oscillator could also afford amplification of weak microwave signals. His objec-

tive was to devise a preamplifier of sensitivity and noise figure comparable to the best of the crystal-mixer receivers available at that time.

To study the possibilities of the helix as a non-resonant slow wave propagation and amplification device, Kompfner, in April of 1943, constructed a tube like that illustrated in Fig. 3, in which input and output elements matched to the helix were achieved by coupling the ends of the helix across the gaps of cavity resonators. The character of the axial electric field within the helix and between the helix and the coaxial outer conductor surrounding it was explored by observing the deflection on a fluorescent screen of an electron beam when radio frequency power was sent through the helix; it was discovered that the longitudinal field near the helix was much more intense than that near its axis. Further experiments with this tube structure showed the utility of the helix as an electronic amplification mechanism. In Kompfner's own words:

> When the radio frequency power emerging from the helix with the beam switched on was compared with the radio frequency power without the beam, it was found that at a beam voltage of 2440 volts there was an increase of 49 per cent, while at a beam voltage of 2200 volts, there was a decrease of 40 per cent.

A tube was then designed with input and output matching sections less restricted in band width, as shown in Fig. 4; it was tested for the first time in December of 1943. A ¼-in. diameter copper wire helix of 66-cm. length with five turns per cm. was supported on dimples in a

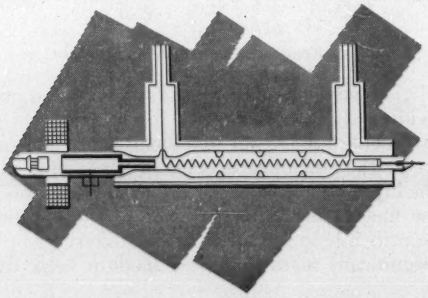

FIG. 4. Kompfner's improved amplifier was tested for the first time in December, 1943.

glass envelope in order to remove the lossy glass from the vicinity of the helix and was coupled at each end to matched coaxial line transformers. A solenoid was used to provide magnetic focusing of the electron beam. The cold insertion loss of the tube was about 3.5 db. With an electron beam of 119 microamp at 1830 volts, a power amplification of 6 was achieved, with an over-all noise factor from 20 db. to 14 db. for a 9.1-cm. input signal wavelength. It was observed that the noise factor of the

tube depended upon the fraction of the beam current arriving at the collector electrode. With a design further improved by the use of a quartz vacuum envelope, a net power amplification of 14 was obtained using a beam current of 50 microamp, of which 80 per cent passed through the helix to the collector electrode, the noise factor of the tube being reduced to 11 db. The helix employed was wound of 22-gauge copper wire on a $\frac{3}{16}$-in. mandrel and was 60 cm. long with about seven turns per cm. Thus, the theoretical consideration that the operation of the tube depends on having the traveling wave and the electrons moving at very nearly the same velocity was again confirmed experimentally.

In theoretical studies completed before the end of 1944, Kompfner, neglecting attenuation in the helix and the effect of space charge, developed first and higher order theories for the power amplification of the helix tube and for its noise factor. In starting the study, Kompfner first considered transverse and axial radio frequency modulation effects in the electron beam, ignoring the result of the inherent reaction of such modulations on the traveling wave itself. Secondly, the study turned to the effects produced in the wave by a modulated electron beam, considering the voltage of the wave thus induced in the line by transverse displacement modulation and that induced by density modulation. Finally, he considered the case in which modulation on the beam had been created by a traveling wave, and calculated the influence of such modulation in the beam on the wave itself. When the total effect of an infinite number of actions and reactions between the beam and the wave was summed, the complete degree of interaction was derived. The important result was observed that the wave tends to grow exponentially with distance down the propagating line.

EARLY RESEARCH ON THE HELIX AMPLIFIER IN UNITED STATES

The first public announcement of the results of British wartime investigation of the helix amplifier as a low noise tube was made by J. Hatton at the Fourth Institute of Radio Engineers Electron Tube Conference at Yale (June 1946). At this conference, work in this country performed at the Bell Telephone Laboratories was revealed by J. R. Pierce and L. M. Field, these engineers emphasizing the broad band and efficiency features of the amplifier. There then occurred a series of publicity releases in the United States and in England on this subject matter (**13**, **14**, **15**, **16**, **17**), and R. Kompfner's initial paper (**12**) (November 1946) appeared in England; the latter spoke of the Bell Laboratories amplifier in some detail, as follows:

> Using a helix of iron wire of 30 cm. length, with an initial attenuation of 33 db., and an electron beam of 1,600 volts and 10 milliamperes, a power amplification of 200 was obtained over a bandwidth of 800 Mc/s to points 3 db. down on the gain/frequency curve. . . ., an R. F. output of 200 milliwatts was obtained. A long solenoid was used to get the beam through to the collector. The mid-frequency was 4,000 Mc/s.

Following these announcements, there appeared in February of 1947 three now well known papers in the *Proceedings of the Institute of Radio*

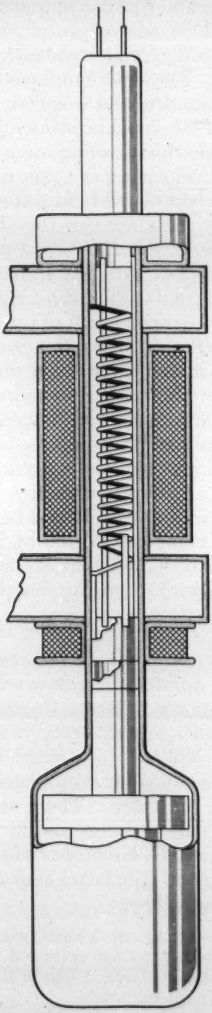

FIG. 5. The Pierce-Field-Best amplifier used a copper helix as the wave propagation medium.

Engineers which are of marked significance. Although they are not the first detailed publications on the traveling wave amplifier, they were important because they, for the first time, presented in the United States qualitative analyses of the theory of the traveling wave amplifier. These three papers include a joint discussion by J. R. Pierce and L. M. Field (18) of experimental results, a paper by J. R. Pierce (19) on the theory of the amplifier, and the companion paper by R. Kompfner (12), the contents of which have been discussed above.

As to the Pierce-Field paper (18), it concerned a recently tested improved helix tube. This amplifier employed a helix supported by longitudinal ceramic rods within the tubular glass envelope, the helix being designed so that in the absence of the electron beam, a wave propagating down the tube would travel at about one-thirteenth the velocity of light. The ends of the helix formed, as in Fig. 5, antenna stubs lying parallel to the axis of the tube, these antennas coupling to input and output wave guides. A long focusing solenoid and an auxiliary coil at the input of the helix insured the passage of most of the beam current to the collector. Typical of this tube were the following operating characteristics:

Beam voltage	1670 v
Cathode current	8 milliamp
Collector current	6 milliamp
Gain at 3600 mc	23 db.
Bandwidth between 3-db. points	800 mc.
Power output	200 milliwatts
Cold transmission loss	33 db.

The amplifier had a copper helix as a wave propagation medium, and as an additional feature, it used attenuation external of the helix to discourage self-oscillation. The attenuation was provided by coating the ceramic supporting rods with a thin layer of high resistance colloidal graphite (20). Near the midpoint of the helix, as in Fig. 6, the con-

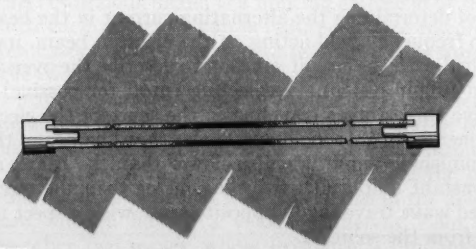

FIG. 6. Helix support structure for the Pierce-Field-Best amplifier which is pictured in Fig. 5.

ductivity of the coating was increased by an amount designed to provide the dissipation of back-fed energy with a minimum of reduction in the amplitude of the useful growing wave. This structure affords the advantage of allowing direct control over the amount of attenuation used to prevent self-oscillation.

The Pierce-Field (18) paper and the earlier paper of December 1946 by J. R. Pierce (17) both contain interesting hints about the principle of operation of the new traveling wave amplifier. It was observed that the complex behavior of the device could be described in terms of three different waves excited about equally on the helix by the input signal, these waves traveling down the propagating structure without mutual interaction. With no electron stream present, only one sort of wave can travel on the helix, and it can travel in both directions. In the presence of the electron stream, it was noted by Pierce that three different sorts of waves travel in the same sense as the electrons. One of these is attenuated with distance, the second is unattenuated, and the third wave is a growing wave; it is clear that the latter wave becomes predominant, while the first two can usually be neglected. This multiple wave hypothesis accounted for the experimental observation of an exponential increase in radio frequency signal amplitude with distance along the tube, the exponential relation starting a short distance after the growing wave becomes predominant.

The theory of this type of wave propagation mechanism was discussed in greater detail in J. R. Pierce's paper (19), using what is now termed the method of expansion in the normal modes of propagation. The small-signal analysis presented there is in terms of a combination of several possible space charge and circuit waves. There is assumed no transverse motion of the electrons and the existence of a strong constant axial magnetic field in the region of the beam; in effect, a one dimensional problem is considered.

As to the circuit problem, the field acting on the beam is set up in terms of the driving alternating current due to the beam as the sum of fields due to a number of transmission modes. The electronic problem being that of determining the alternating current in the beam in terms of the radio frequency field acting on the electron beam, its solution is then combined with the circuit solution to describe the over-all behavior of the beam-circuit system. Neglecting cutoff (or passive) modes, the solutions give three waves traveling in the sense of the electron beam, one an exponentially growing wave slower than the beam, the second a wave of diminishing amplitude also slower than the beam, and a third wave, of constant amplitude, traveling faster than the electrons. An unattenuated wave traveling in opposite sense with respect to the beam also results from the solution.

Pierce calculated the gain of the amplifier in terms of these three forward waves, assuming the tube to be terminated so that no reflected

wave is created, having first found expressions for the dependence of the propagation coefficients on beam voltage and current and on circuit losses. He found an expression for the gain of the amplifier and made an estimate, limited by his small signal assumptions, of limiting power output and of efficiency. An estimated noise figure was also derived.

EARLY THEORETICAL STUDIES OF THE TRAVELING WAVE AMPLIFIER IN FRANCE

Actually, the first publication of a theoretical study of the traveling wave amplifier had already appeared as a paper published in France in December 1946; it was an analysis by A. Blanc-Lapierre and P. Lapostolle (21, 22). These engineers presented a study of the energy interaction between a traveling wave propagating along a delay line and an electron beam of velocity approximately equal to that of the wave, assuming small variations in the beam velocity and density. As a model for the delay line, they made use of a circuit representing a lineal grouping of resonant cavities coupled by axially aligned apertures so as to form a slow wave propagation structure. Discontinuous and continuous versions of this model were analyzed.

In the study of the discontinuous model, the interaction of an electron beam with the electric fields lying within a succession of pairs of electron permeable condenser plates of an infinite delay line is calculated. The arrangement is similar to a velocity modulation amplifier in which the energy exchange, in lieu of being effected in a single gap, is made in a discontinuous manner, the field operating successively on the electron beam to amplify the radio frequency energy, leading to an exponential power increase. Two waves flowing in the sense of the electron beam are shown to exist; one is positively attenuated and has a velocity slightly less than the electron beam. The other wave has the same velocity as the attenuated wave, but increases in amplitude exponentially with distance traveled down the propagation structure. When Blanc-Lapierre and Lapostolle turned next to consideration of the continuous model, evidence for the existence of four waves was derived. This continuous model is a limiting extension of the previous model in which each resonator gap is reduced in size toward zero, the number of resonators being increased to infinity. It is shown that, in addition to the two waves of the discontinuous model, two further waves having zero attenuation (assuming a lossless line) are defined, both waves having a velocity slightly greater than the electron beam. One wave flows in the sense of the beam, while the other travels in the opposite sense. Thus, two of the four waves derive from the usual single wave and from the usual reflected wave in the line in the absence of the electron beam, though having a velocity different from the parent waves. The other two waves, whose existence is fundamentally connected with the presence of the electron beam, are propagated with a lesser velocity than the parent waves; they flow always in the same sense

as the electrons. M. J. Vogue (23) presented a companion paper in 1946, in which a gain per wavelength along the axis of such a tube is deduced.

Among other analytical papers on the traveling wave amplifier published during the same early period by French authors were those of R. Wallauschek (24) and P. Lapostolle (25). R. Wallauschek (24) considered a cylindrical wave guide in which all of the cross section is filled with material of high dielectric constant, transmitting a wave in a mode such that the electric field along the axis of the guide is parallel to the axis. The dielectric is pierced by a small diameter bore through which is projected an electron beam of velocity close to the wave velocity. The calculation describes two waves, one growing and the other diminishing in amplitude, these waves having a phase velocity lower than the beam velocity; also predicted are the two constant amplitude waves flowing in opposed directions with phase velocities greater than the velocity of the electrons. Wallauschek's approach was extended by P. Lapostolle (25), who considered the same dielectric wave guide model, but did not impose the restriction that the axial electric component of the wave is constant across the section of the beam.

An early paper by J. Bernier (26, 27) also set down a simple theory of the traveling wave amplification mechanism. This is a small signal study involving the interaction of the modulating longitudinal field with the modulated current of the electron beam, the calculation of the field of the transmission line when there are distributed energy sources along the line, and the coupling of the beam to the line. The resulting characteristic equation is solved assuming zero and then finite attenuation for the line, predicting a wave which is resolvable into four components of which only one, practically speaking, exists at the output of the tube. The gain of the amplifier is shown to increase exponentially with tube length and as the third root of beam current. Further predicted is the sensitivity of gain to the velocity of the electron beam relative to that of a freely propagated wave in the circuit. Bernier also calculated the limiting gain attainable with a tube of predetermined circuit attenuation, beam velocity, and input signal frequency. The pass band of the tube is shown to decrease when one increases gain by increasing the beam current. The analysis was extended to multiple mode transmission, as in a wave guide substantially filled with dielectric. Here, the characteristic equation has an infinite number of roots, predicting an infinity of excited waves, only one of which is, of course, particularly amplified. Lapostolle (28, 29) continued consideration of multi-mode transmission in the same model.

CONCLUSION

This paper has traced the published history of the traveling wave-electron beam interaction principle from its origin in K. Posthumus'

magnetron oscillator through the critical early period of its establishment in the modern traveling wave amplifier. Analytic and experimental results produced during that critical era in the United States, England, and France have been considered. Activity in developing and using traveling wave tubes in these countries and in others has remained to the present date at a very high level; those authors mentioned in the bibliography have continued to contribute and many others have joined the list of research workers in the field. Now well established as a practical microwave relay amplifier tube, the traveling wave amplifier is certain to find many applications in the future as a low noise amplifier, power amplifier, tunable oscillator and amplifier, and otherwise in future communication, radar, and navigational systems.

REFERENCES

(1) A. ZACEK, *Casopis pro Pestovani Mathematiky a Fysiky* (Prague), Vol. 53, p. 378 (1924). Summary in *Zeitschrift fur Hochfrequenz-Technik*, Vol. 32, p. 172 (1932).

(2) E. HABANN, "Eine Neue Generaturohe," *Zeitschrift fur Hochfrequenz-Technik*, Vol. 24, No. 5, pp. 115–120 (1924).

(3) K. POSTHUMUS, "Oscillations in Split-Anode Magnetron," *Wireless Engineer and Experimental Wireless*, Vol. 12, pp. 126–132 (1935).

(4) J. C. SLATER, "Microwave Electronics," *Rev. Modern Physics*, Vol. 18, pp. 441–512 (1946).

(5) J. C. SLATER, "Microwave Electronics," New York, D. Van Nostrand Company, Inc., 1940.

(6) J. T. RANDALL, "The Cavity Magnetron," *Proc. Physical Soc.*, Vol. 58, pp. 247–252 (1946).

(7) G. B. COLLINS, "Microwave Magnetrons," M. I. T. Radiation Laboratory Series, Vol. 6, New York, McGraw-Hill Book Company, Inc., 1948.

(8) J. B. FISK, H. D. HAGSTRUM AND P. L. HARTMAN, "The Magnetron as a Generator of Centimeter Waves," *The Bell System Technical Journal*, Vol. 25, April, 1946.

(9) R. L. WATHEN, "Genesis of a Generator—The Early History of the Magnetron," JOUR FRANKLIN INST., Vol. 255, pp. 271–287 (1953).

(10) A. V. HAEFF, U. S. Patent #2,064,469, filed October 23, 1933, issued December 15, 1936; A. V. HAEFF, U. S. Patent #2,233,126, filed October 23, 1933, issued February 25, 1941.

(11) N. E. LINDENBLAD, U. S. Patent #2,300,052, filed May 4, 1940, issued October 27, 1942.

(12) R. KOMPFNER, "The Traveling Wave Valve," *Wireless World*, Vol. 52, pp. 369–372 (1946); R. KOMPFNER, "The Traveling Wave Tube as an Amplifier at Microwaves," *Proc. I. R. E.*, Vol. 35, pp. 124–127 (1947); R. KOMPFNER, "The Travelling Wave Tube," *Wireless Engineer*, Vol. 53, pp. 255–266 (1947); R. KOMPFNER, "On the Operation of the Traveling Wave Tube at Low Level," *British Inst. Radio Engineers*, pp. 283–289 (1950); R. KOMPFNER, "Travelling Wave Tubes," *Reports on Progress in Physics*, Vol. 15, London, The Physical Society, 1952; R. KOMPFNER, U. S. Patent #2,653,270, filed June 19, 1947, issued September 22, 1953.

(13) M. A. BARTON, "Traveling Wave Tubes," *Radio*, Vol. 30, pp. 11–32 (1946).

(14) "Wideband Microwave Amplifier Tube," *Electronics*, Vol. 29, pp. 90–92 (1946).

(15) "Beam Traveling Wave Amplifier Tube," *Rev. Scientific Instruments*, Vol. 17, pp. 559–560 (1946).

(16) "Broad Band Tube," *Electronic Industries*, Vol. 5, pp. 57–103 (1946).

(17) J. R. PIERCE, "The Beam Traveling-Wave Tube," *Bell Laboratories Record*, pp. 439–442 (1946).

(18) J. R. PIERCE, AND L. M. FIELD, "Traveling Wave Tubes," *Proc. I. R. E.*, Vol. 35, pp. 108–111 (1947).

(19) J. R. PIERCE, "Theory of the Beam Type Traveling Wave Tube," *Proc. I. R. E.*, Vol. 35, pp. 111–123 (1947).

(20) L. M. FIELD, U. S. Patent #2,575,383, filed October 22, 1946, issued November 20, 1951; J. R. PIERCE, U. S. Patent #2,602,148, filed October 22, 1946, issued July 1, 1952.

(21) A. BLANC-LAPIERRE AND P. LAPOSTOLLE, "Contribution a l'etude des amplificateurs a ondes progressives," *Annales des Telecommunications*, Vol. 1, pp. 283–302 (1946).

(22) A. BLANC-LAPIERRE AND P. LAPOSTOLLE, "Sur l'interaction entre une onde progressive et un faisceau d'electrons de vitesse voisine de celle de l'onde," *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences*, Vol. 224, pp. 104–105 (1947).

(23) M. J. VOGUE, "Sur deux schemas d'amplificateurs electroniques pour tres hautes frequences a onde progressive," *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences*, Vol. 223, pp. 1117–1119 (1946).

(24) R. WALLAUSCHEK, "Sur un amplificateur electronique a onde guidee dans un milieu de constante dielectrique elevee," *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences*, Vol. 224, pp. 191–193 (1947).

(25) P. LAPOSTOLLE, "Etude de la propagation simultanee d'une onde progressive guidee et d'une faisceau electronique de vitesse voisine," *Comptes Hebdomadaires des Seances de l'Academie des Sciences*, Vol. 224, pp. 268–270 (1947).

(26) J. BERNIER, "Essai de theorie du tube electronique a propagation d'onde," *Annales des Radioelectricite*, Vol. 2, pp. 87–101 (1947).

(27) J. BERNIER, "Essai de theorie du tube electronique a propagation d'onde," *L'Onde Electrique*, Vol. 27, pp. 231–243 (1947).

(28) P. LAPOSTOLLE, "Etude de diverses ondes progressives guidees susceptibles de se propager en interaction avec un faisceau electronique," *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences*, Vol. 224, pp. 558–560 (1947).

(29) P. LAPOSTOLLE, "Generalizations de certains resultats relatifs a l'interaction d'ondes guidees avec un faisceau electronique," *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences*, Vol. 224, pp. 814–816 (1947).

PRIMARY ALPHA PARTICLES IN THE COSMIC RADIATION NEAR THE GEOMAGNETIC EQUATOR *

BY

MARTIN A. POMERANTZ [1]

ABSTRACT

An apparatus consisting of a G-M counter coincidence train in which is interposed a high-pressure ionization chamber has been utilized to obtain measurements of the flux of primary helium nuclei during a series of balloon-flights in India. The instrument records relativistic particles characterized by a specific ionization at least as great as that of an alpha particle.

The experiments were conducted at Aligarh, Uttar Pradesh (geomagnetic latitude 18° N) and Bangalore, Mysore (geomagnetic latitude 3° N). At each station, the intensity $N(I > 3.2I_{\min})$ of particles producing ionization chamber pulses exceeding the bias setting corresponding to $3.2I_{\min}$, plotted on a logarithmic scale as a function of atmospheric depth, follows a straight line. The intensity N_{total} was also measured by removing the criterion $I > 3.2I_{\min}$.

Taking into account local nuclear interactions initiated by protons, knockon electrons accompanying protons, and slow protons (albedo) which actuate the apparatus, the alpha-particle flux is determined from the extrapolated values of N_{total} and $N(I > 3.2I_{\min})$ at the "top of the atmosphere." The results are:

49 ± 13 particles m^{-2} sec^{-1} sterad^{-1} at $\lambda = 3°$ N, and

81 ± 22 particles m^{-2} sec^{-1} sterad^{-1} at $\lambda = 18°$ N.

The qualitative effect of the presumably small systematic uncertainties is generally in the direction of making these values low. Both protons and helium nuclei can be represented by an integral energy distribution of the form:

$$N(> E) = k(1 + E)^{-1.3},$$

where E is kinetic energy per nucleon; $k = 4000$ and $1.5 < E < 15$ Bev for protons; $k = 450$ and $0.3 < E < 7$ Bev per nucleon for alpha particles.

The composition of the primary cosmic radiation is not drastically different at $\lambda = 3°$ and $\lambda = 18°$, although the total intensity is anomalously high at the latter station.

I. INTRODUCTION

Since the presence of primary cosmic rays of charge $Z > 1$ was first detected in 1947, all of the available experimental techniques have been utilized for determining the values of the flux of the various components (1).[2] Because helium, which is by far the most abundant incoming element with the exception of hydrogen, represents a large percentage of the incident nucleons, information regarding the relative intensity and energy spectrum of the primary alpha particles is of considerable importance to cosmic-ray phenomenology and theory.

* Supported by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission. Field expedition sponsored by the National Geographic Society.

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

Unfortunately, regardless of the particular method of measurement which has been adopted, complicating factors have precluded attaining the desired precision, and the various determinations have differed appreciably. The principal difficulty arises from the fact that, even at high altitudes, the number of secondary particles having the same specific ionization as relativistic alpha particles is appreciable. Thus, it is necessary to correct for the background of atmospheric origin by invoking some criterion which, in general, inevitably biases the selection either by rejecting some primary nuclei with $Z = 2$, or accepting some particles with $Z \neq 2$.

Measurements of the alpha-particle flux have been obtained at latitudes north of $\lambda = 30°$ with trains of low pressure counters (2), with photographic emulsions (3), and with G-M counter trains in which were interposed either a proportional counter (4), a low-pressure counter (5), a Čerenkov detector (6), a scintillation counter (7), or a cloud chamber-Čerenkov detector combination (8). The only related data referring to the equatorial region were obtained in a single rocket firing, with an apparatus which measured the efficiency of a low-pressure counter inserted into a counter train (9). This measurement was consistent with a primary beam composed of protons only. Inasmuch as helium nuclei having energies exceeding the geomagnetic cutoff at the equator had been identified in photographic emulsions, and in view of the fact that the spurious effects which influence experiments of this type tend to yield too high a value for the counter efficiency, and hence are expected to lead to an overestimate of the alpha-particle flux, this result was surprising.

In order to facilitate a detailed investigation of the alpha-particle component in the vicinity of the geomagnetic equator, a new method of detection which appeared to embody certain experimental and operational advantages was developed for making radio-telemetered observations during an extensive program of balloon flights in India during 1952–53. It was recognized at the outset that the interpretation of the radio-transmitted data obtained in India with the basic unit would be contingent upon certain detailed information to be provided by a single more elaborate control experiment incorporating supplementary means for studying the inevitable spurious effects, and involving a photographic recording system. The apparatus developed for this purpose by G. W. McClure was subsequently carried aloft by a Skyhook balloon during the Project Churchy Expedition to the Galapagos Islands in September, 1953.

II. EXPERIMENTAL PROCEDURE

A. Method

In the present experiments, relativistic alpha particles are identified on the basis of specific ionization plus residual range. This is accomplished with the arrangement shown in Fig. 1, consisting of a G-M

counter coincidence train in which is interposed a high-pressure ionization chamber with a lead absorber underneath. As is evident in Fig. 2, in which the ionization of the various charged components of the cosmic radiation is plotted as a function of residual range, any particle capable of actuating all of the counters must be relativistic when it passes through the chamber, that is, it ionizes at practically the minimum rate corresponding to its charge, Z. Singly-charged particles (electrons, mesons, protons) which discharge all four counters produce a pulse of magnitude I_{min}. Owing to the statistical fluctuations in the total number of ions produced in the gas of the chamber by a given particle

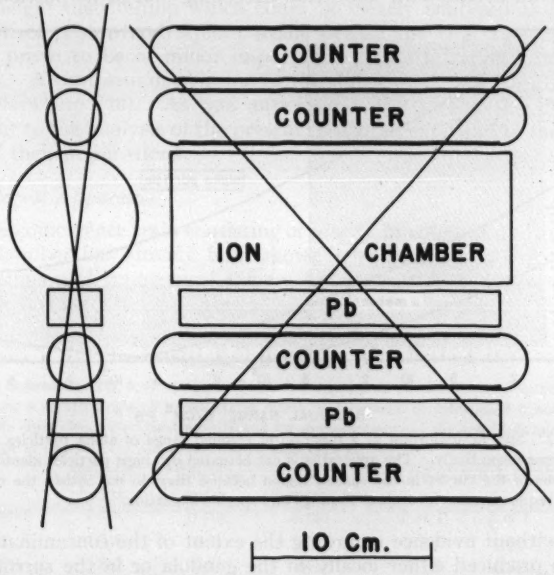

FIG. 1. Schematic diagram of counter-ionization chamber coincidence train.

(Landau spread) and because of the variations in the path length through the chamber on account of the finite dimensions of the counter train, there is a spread in the size of the ionization pulses associated with a particle of specified Z. However, the shapes of the respective distributions are such that substantially every alpha particle and no relativistic proton which penetrates the absorber within the solid angle of the telescope should produce a pulse of ionization exceeding $3.2I_{min}$.

Thus, when the apparatus is biased so that only cosmic rays which yield a pulse greater than $3.2I_{min}$ can register, in principle it counts only fast particles with $Z \geq 2$, which are predominantly primary helium

nuclei. This type of instrument (hereinafter designated *integral*) which measures the total intensity of relativistic particles characterized by a specific ionization exceeding a fixed lower limit, was especially suitable for the observations of the latitude effect in the equatorial regions in India.

As has already been noted, the integral type of apparatus was not regarded as a completely adequate indicator of the flux of primary heavy nuclei without the benefit of certain supplementary information which it was recognized would be required for a careful analysis of the experimental results. In particular, it was realized that one could not safely identify all events with ionization exceeding $3.2I_{\min}$ as particles with

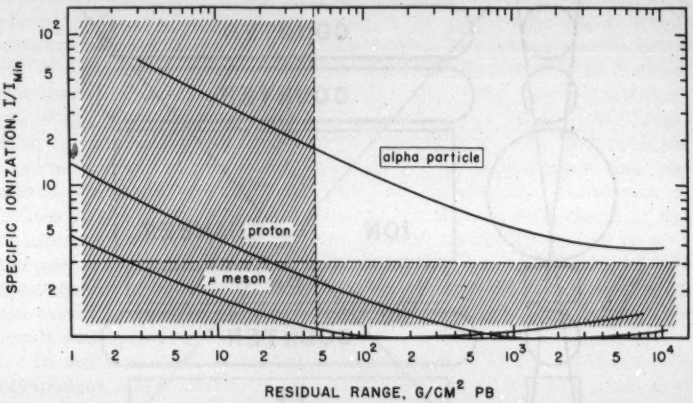

FIG. 2. Specific ionization as a function of residual range of alpha particles, protons, and μ-mesons respectively. The apparatus is not actuated by single particles identified with the portions of the curves in the shaded region because they do not satisfy the combined minimum requirements with respect to range and specific ionization.

$Z \geq 2$ without evidence regarding the extent of the contamination by showers produced either locally in the gondola or in the surrounding atmosphere.

On the basis of existing knowledge of nuclear radii, it appeared that a substantial fraction ($\sim$30 per cent) of the energetic protons incident upon the apparatus would produce some sort of nuclear interaction within the instrument.

Most of the local interactions occur in the Pb absorber beneath the ion chamber, and a rather high multiplicity of secondaries moving in the backward direction and escaping from the top of the lead is required to actuate the apparatus. Nevertheless, the possibility that such events might interfere with the alpha-particle flux determination could not be precluded.

With the object of ascertaining the degree of interference from local interactions and showers, an arrangement having nearly the same geometrical features as the integral instrument, but incorporating in addition a multi-counter shower detector and pulse-height recorder was designed by G. W. McClure. This apparatus (hereinafter referred to as *differential*) provides a determination of the ionization spectrum of relativistic particles as well as an indication of the extent to which multiple-particle events may be responsible for ionization pulses of magnitude greater than that which could be attributed to one singly-charged particle. It was hoped that this instrument would reveal a pulse-height distribution which could be clearly analyzed as a superposition of proton and alpha-particle peaks, and that shower events might prove to be of minor importance in the interpretation of the results. A complete description of the differential experiment will appear elsewhere (10). As was anticipated, the results therefrom are relevant to the analysis of the present measurements, and to the discussion of their implications.

B. Integral Apparatus

The coincidence train consisting of four G-M counters and an ionization chamber has already been shown schematically in Fig. 1. The dimensions and geometrical factors for converting counting rates to particle flux are listed in Table I.

TABLE I.—*Geometrical Factors for Converting Counting Rates into Absolute Particle Intensities.*

p is defined by: $I(\theta, h, t) = I(0, h, t) \cos^p \theta$, I represents particle flux, N counting rate of apparatus, θ zenith angle, h atmospheric depth, t thickness of interposed absorber. The quadruple coincidence counter train utilized for measurements of the total intensity is designated type A (see ref. 17), the present apparatus type C.

Instrument	Effective length, l cm.	Effective width, w cm.	Separation, L cm.	$\varphi = N(0, h, t)/I(0, h, t)$ $p = 2$	$p = 1$	$p = 0$
A	19.4	0.9	11.5	1.23	1.29	1.45
C	18.2	3.0	24.7	4.18	4.32	4.50
φ_C/φ_A				3.40	3.35	3.10

The counters are glass-walled, with internal aquadag cathodes and 0.003-in. tungsten anode wires. They are filled to a total pressure of 10 cm. of Hg with a mixture composed of 86 per cent argon and 14 per cent butane, and operate at a potential of 1035 volts. During a comprehensive series of tests the effective ends of the sensitive volume of each counter were located individually by essentially the method employed earlier (11).

The internal features and preparation of the high-pressure (300 psi. argon) electron-collection ionization chambers (Fig. 3) are similar to those of the low pressure (75 psi.) chambers described previously (12).

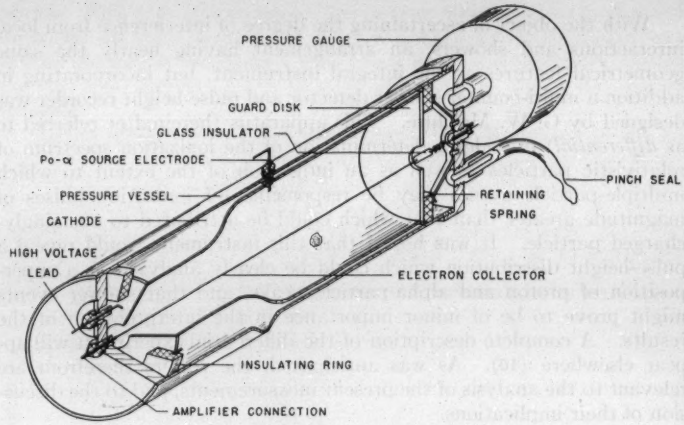

FIG. 3. Constructional details of the high pressure ionization chamber. The filling was 300 psi. of argon.

Although the 300-psi. chambers required more careful cleaning and outgasing prior to filling, ordinary tank argon (99.9 per cent purity) proved adequate for the production of chambers in which the Po-alpha pulses attained voltage saturation at cathode potentials of 800 to 900

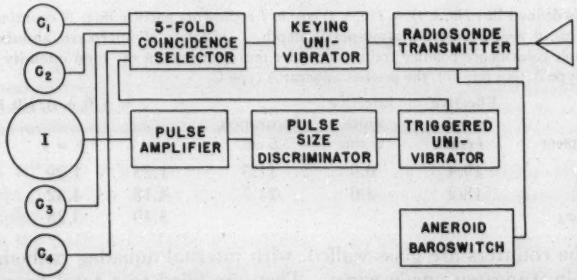

FIG. 4. Block diagram of the circuits associated with the counter-ionization chamber coincidence train.

volts. Thus, the 1035-volt battery supply for the G-M counters provided ample voltage for the operation of the ion chambers.

Figure 4 is a block diagram of the circuits associated with the counter-ion chamber coincidence train. The linear amplifier following

the ionization chamber comprises three stages with 0.025 per cent inverse feedback and a voltage gain of 4000. The amplifier rise time was adjusted to a value (~10 μsec.) which yielded the best signal to noise ratio consistent with the preservation of the shape of the leading edge of the ion-chamber pulses. By exercising care in the selection of the 6AK5 amplifier input tubes it was possible to attain an output noise level less than one-tenth the average height of the pulses produced by sea-level mesons.

Any pulse which is larger than the preassigned minimum determined by the bias setting of the pulse-size discriminator triggers the univibrator, which then delivers to the coincidence-selector stage a pulse of the same height and shape as those arriving from the G-M counters.

The remaining components of the balloon-borne apparatus, and the telemetering system, were similar to those utilized in the other phases of the program, and with the exception of certain minor modifications the general features have been described previously (13). A cyclic-type barograph with nesting sensitive bellows provided continuous pressure signals over a separate radio transmitter during flights designed to level off or change altitude slowly in the upper atmosphere.

By means of a pressure-actuated switching arrangement, which biased off the ionization chamber stage of the coincidence-selector circuit at predetermined altitude intervals, the total counting rate of all particles passing through the counter train, regardless of specific ionization, was measured alternatively in the upper atmosphere during some of the flights. A coded sequence of audio-modulated signals continuously indicated the prevailing state as well as the atmospheric pressure.

During the preflight ground-run of each instrument immediately prior to release, the integral pulse-height distribution curve characteristic of the cosmic rays near sea level was obtained by recording counting rate as a function of bias setting. This served to check the over-all operation of the instrument, and yielded a calibration for setting the bias to correspond to pulses of ionization exceeding $3.2I_{min}$. The data thus obtained with a number of the instruments are plotted in Fig. 5. There is satisfactory agreement between the points and the solid line which is derived from the differential pulse-height distribution obtained at sea level (14) at $\lambda = 52°$. The latter is in accord with the calculated distribution based upon the known meson spectrum and the Landau-Symon (15, 16) theory of ionization fluctuations. An additional instrumental test was provided by the pulses produced by the alpha particles emitted from the polonium source which can be turned "on" or "off" by the application of appropriate voltage to the probe. The minimum accepted pulse height, equivalent to $3.2I_{min}$, established by the bias setting during the flights, corresponds to about 0.13 Po-alpha.

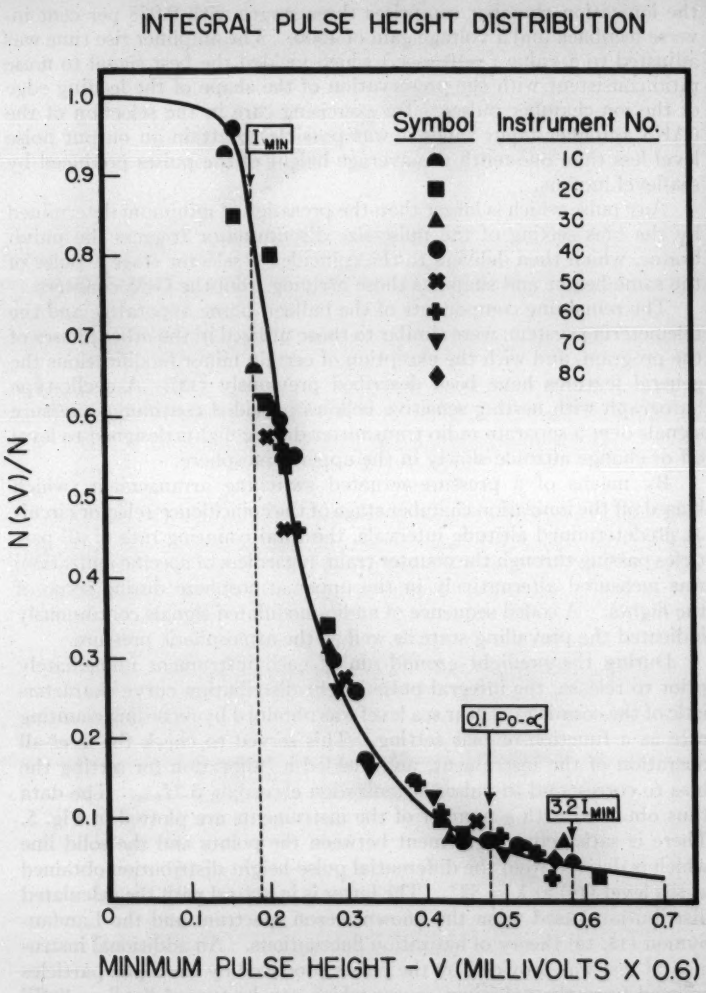

FIG. 5. Integral pulse-height spectrum at sea level. The curve represents the distribution observed at Swarthmore, Pennsylvania (geomagnetic latitude 52° N) whereas the points were obtained during ground runs of the balloon-borne instruments at Aligarh, Uttar Pradesh (geomagnetic latitude 18° N) and Bangalore, Mysore (geomagnetic latitude 3° N).

III. RESULTS

A. *Balloon-Flight Data*

The series of balloon flights in which the measurements presented in this section were obtained is summarized in Table II. The data re-

TABLE II.—*Summary of Balloon-Flights Comprising the Present Series.*

Flight No.	Date	Station	Ceiling altitude, ft.	Remarks
1C	2-18-53	Aligarh	103,000	Slow descent
2C	2-26-53	Aligarh	90,000	
3C	4-11-53	Bangalore	72,000	Level, 5½ hr.
4C	4-18-53	Bangalore	87,000	Level, 2½ hr.
5C	4-23-53	Bangalore	83,000	Level, 7 hr.
6C	5-3-53	Bangalore	70,000	
7C	5-30-53	Aligarh	84,000	Level, 4 hr.
8C	6-5-53	Aligarh	73,000	Level, 1¾ hr.

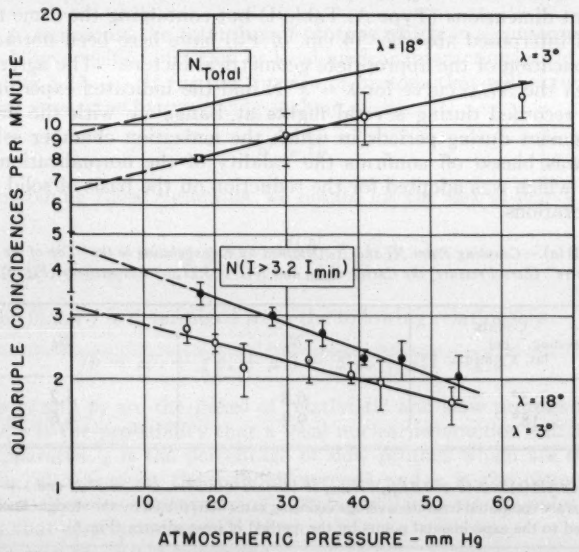

FIG. 6. Dependence upon atmospheric pressure of the counting rates at Aligarh and Bangalore, India. The curves $N(I > 3.2I_{min})$ are fitted by the method of least squares to the points representing the combined data recorded during the various individual flights. The curves N_{total} were derived from a separate series of measurements of the total intensity of particles penetrating the same amount of interposed absorber, and the corresponding experimental points at $\lambda = 3°$ were obtained with counter-ion chamber instruments equipped with an arrangement for removing the requirement $I > 3.2I_{min}$ at predetermined pressure intervals.

corded during the individual flights at each of the two stations, Aligarh, Uttar Pradesh (geomagnetic altitude 18° N) and Bangalore, Mysore (geomagnetic latitude 3° N) were in agreement within statistical expectations.

All of the data in a specific altitude interval during both ascent and descent of the several instruments have been combined in Fig. 6, in which counting rates are plotted on a logarithmic scale as a function of atmospheric pressure. The points for $N(I > 3.2I_{min})$ follow the straight lines which have been fitted by the method of least squares. The indicated uncertainties are statistical standard deviations, and the extrapolated values at zero pressure are established by the least squares analysis.

The curves N_{total} represent the counting rates when the criterion $I > 3.2I_{min}$ is removed. In this case, the solid lines are derived from a related series of experiments performed concurrently in India and already described in another publication (17). The intensity measurements obtained with a quadruple-coincidence counter train of somewhat different dimensions (Type A, Table I) but containing the same thickness of interposed absorber (4 cm. of Pb) have here been normalized by application of the appropriate geometrical factors. The agreement between the N_{total} curve for $\lambda = 3°$ N and the indicated experimental points recorded during several flights at Bangalore with the present arrangement during periods in which the ionization chamber selector stage was biased off confirms the validity of the normalization procedure which was adopted for the reduction on the basis of solid angle considerations.

TABLE III(*a*).—*Counting Rates N_1 and N_2 Obtained by Extrapolating to the "Top of the Atmosphere" (Zero Pressure) the Curves N_{total} and $N(I > 3.2I_{min})$ Respectively (Fig. 6).*

Geomag. lat, λ \ Counts per min.	N_1	N_2
3°	6.8	3.2
18°	9.2	4.6

TABLE III(*b*).—$N(I > 3.2I_{min})/N_{total}$ *at Various Altitudes, at* $\lambda = 3°$ *N and* $\lambda = 18°$ *N.* The ratios are computed from the average counting rates determined by the straight lines which were fitted to the experimental points by the method of least squares (Fig. 6).

Atmospheric pressure, mm. of Hg		0	10	20	30	40	50
$\frac{N(I > 3.2I_{min})}{N_{total}}$	$\lambda = 3°$	0.47	0.37	0.30	0.24	0.19	0.15
	$\lambda = 18°$	0.50	0.38	0.29	0.23	0.17	0.14

The significant experimental quantities at each of the two latitudes are N_{total} and $N(I > 3.2I_{\text{min}})$ at the "top of the atmosphere" (extrapolated values). These are summarized in Table III, which also lists $N(I > 3.2I_{\text{min}})/N_{\text{total}}$ at several altitudes. Within the statistical uncertainties, these ratios do not vary between Aligarh and Bangalore.

B. Analysis

If p is the primary proton flux, and α is the flux of incoming nuclei with $Z \geq 2$, the total particle flux, N_{total}, at the "top of the atmosphere" at a particular latitude is

$$N_{\text{total}} \equiv N_1 = p + \alpha. \tag{1}$$

The flux $N(I > 3.2I_{\text{min}})$ of particles which produce pulses of ionization exceeding the bias setting of the apparatus is

$$N(I > 3.2I_{\text{min}}) \equiv N_2 = p' + \alpha. \tag{2}$$

Here, p' represents the total flux of protons which as a consequence of either large specific ionization or local nuclear interactions yield pulses exceeding $3.2I_{\text{min}}$. If f is the fraction of protons that will actuate the integral apparatus by producing such an event,

$$p' = fp. \tag{3}$$

Combining these equations, we obtain for the flux of heavy nuclei ($Z > 1$):

$$\alpha = N_2 - \frac{f(N_1 - N_2)}{1 - f}. \tag{4}$$

The factor f is determined from the following relationship:

$$fp = \rho p_r + g\,p_s + \mu(1 - \rho)p_r + \mu(1 - g)p_s \tag{5}$$

where p_r and p_s are the fluxes of relativistic and slow protons respectively, ρ is the probability that a local nuclear interaction will actuate the apparatus, g is the percentage of slow protons which are counted (taking into account the Landau spread) and μ is the chance that knockon electrons accompanying a proton will increase the pulse height above that corresponding to $3.2I_{\text{min}}$.

If $s = p_s/p_r$, Eq. 5 becomes:

$$fp_r(1 + s) = p_r\{\rho + \mu(1 - \rho) + s[g + \mu(1 - g)]\} \tag{6}$$

and

$$f = \frac{\rho + \mu(1 - \rho) + s[g + \mu(1 - g)]}{1 + s}. \tag{7}$$

The results of the differential experiment (10) appear to be compatible with the hypothesis that practically every nuclear interaction which a singly-charged particle undergoes in passing through the apparatus results in an ion-chamber pulse exceeding that characteristic of a relativistic particle with $Z = 1$.

The probability $\rho = 0.27$ is determined from the geometric cross section given by the empirical expression which is applicable to heavy nuclei (1):

$$\begin{aligned} \sigma &= \pi(r_1 + r_2 - 2\Delta r)^2 \\ r &= 1.45 \times 10^{-13} A^{\frac{1}{3}} \\ \Delta r &= 0.85 \times 10^{-13}. \end{aligned} \tag{8}$$

Utilizing a Čerenkov detector, Anderson (18) has measured the flux of slow protons (210–320 Mev) at $\lambda = 10°$. The minimum energy required by a proton to penetrate the apparatus utilized in the present experiments is also approximately 210 Mev, corresponding to the lower limit in Anderson's experiment. The factor g for a slow proton incident from above differs from that for an upward-moving proton having the same momentum initially upon entering the instrument, in view of the fact that the velocity while traversing the ionization chamber is lower in the latter case because most of the absorber is located below the chamber. However, protons with energy exceeding 320 Mev, the upper limit of the slow proton group measured by Anderson, make a negligible contribution to $N(I > 3.2I_{\text{min}})$ even if traveling upward. Hence, Anderson's data are relevant to the present considerations. Although the relative intensities of upward and downward-moving slow protons are not determined by the Čerenkov detector, and statistical and other uncertainties involved in deducing the flux of this component preclude establishing a precise evaluation of the influence of slow protons, Anderson's measurements nevertheless provide an upper limit. For the present purposes, the average value $sg = 0.05$ has been estimated.

The quantity $\mu = 0.03$ is determined from the comparison of the pulse-height distribution observed for mesons at sea level with that expected on the basis of the Landau-Symon theory of statistical fluctuations in the energy loss by collision. The relative contribution to large pulses attributable to knockon electrons accompanying the protons near the "top of the atmosphere" is approximately equivalent to that characteristic of the mesons at sea level. Hence, the tail of the curve above $3.2I_{\text{min}}$ in Fig. 5 represents the effect of delta rays, inasmuch as fluctuations into this region in the ionization by singly-charged particles are negligible.

The primary alpha-particle flux values, $\alpha - Z(> 2)$, at $\lambda = 18°$ and $\lambda = 3°$, computed from Eq. 4 with $f = 0.33$, and N_1 and N_2 as given in Table III, are listed in Table IV. The experimental limits indicated

TABLE IV.—*Values of Flux of Primary Helium Nuclei.*

Station	Geomagnetic latitude, λ	Flux, particles $m.^{-2}$ $sec.^{-1}$ $sterad^{-1}$
Bangalore	3°	49 ± 13
Aligarh	18°	81 ± 22

are determined from the statistical standard deviations in N_1 and N_2. Subject to the hypothesis that the mean free path for nuclear collisions of protons in Pb is represented by Eq. 8, uncertainty in the value of f introduces an error which is smaller than that arising from statistical fluctuations.

IV. DISCUSSION

A. Influence of Disturbing Effects

1. Nuclear Interactions

The accuracy of the determination of the alpha-particle flux with any arrangement basically similar to that utilized in the present experiments is limited principally by the uncertainty regarding the probability that a nuclear interaction initiated by a relativistic proton will cause the apparatus to be actuated. The presence of interposed absorber is, of course, indispensable in order to eliminate slow singly-charged particles which are heavily-ionizing. Hence, the local nuclear interactions cannot be completely avoided. Although their effects might be reduced by increasing the separation between the lead and the ionization chamber, this would also result in an undesirable decrease in counting rates.

It has been assumed that every nuclear interaction produces a count. Any alternative assumption would *increase* the value of the alpha-particle flux. On the other hand, the possible effect of shower particles produced by primaries passing through the interposed absorber outside the solid angle defined by the G-M counters has been neglected. It is not clear how this type of event might affect the results. However, it does not appear possible to reconcile any appreciable contribution of this sort with our previously-reported experimental results regarding the absorption of cosmic radiation at very high altitudes near the geomagnetic equator (17). For example, the *attenuation* of the beam at an atmospheric depth of 18 g. $cm.^{-2}$ is about 7 per cent when the thickness of interposed absorber is increased from 4 cm. to 7.5 cm. of Pb, whereas the addition of this amount of material would almost double the counting rate associated with out-of-line particles. This absorption is consistent with Anderson's intensity measurements of slow protons having energy between 210 and 320 Mev, all of which have ranges between 4 cm. and 7.5 cm. of Pb. Furthermore, absolute particle intensity measurements obtained with different geometrical arrangements are in good

agreement. This could hardly be expected if the width of the interposed absorber were an important factor, which would be the case if events of the type in question were prevalent.

2. Albedo

The effect of slow protons (210–320 Mev) has already been discussed. It was assumed in the analysis that relativistic albedo particles are just as efficacious as the much more energetic primary nucleons in triggering events corresponding to $I > 3.2I_{\min}$. Anderson's experiments (18)

TABLE V.—*Summary of Primary Alpha-Particle Flux Determinations by Various Investigators.*

Geomagnetic latitude, λ	Cutoff energy, Bev per nucleon	Flux, particles m.$^{-2}$ sec.$^{-1}$ sterad^{-1}	Experimental method	Author [a]
55°	0.3	280 ± 8	Scintillation counter	Ney
55°	0.3	340 ± 40	Proportional counter	Davis
51°	0.5	340 ± 120	Photographic emulsion	Goldfarb
55°	0.7[b]	160 ± 27	Cloud Chamber + Čerenkov detector	Linsley
41°	1.6	110 ± 20	Proportional counter	Perlow
30°	3.3–4.3[c]	60 ± 10	Photographic emulsion	Goldfarb
18°	5.1–6.0	81 ± 22	Ion Chamber, integral type	This paper
10°	6.0–6.4	38 ± 6	Ion Chamber, differential type	McClure
3°	6.8	49 ± 13	Ion Chamber, integral type	This paper

[a] References are as follows:

E. P. NEY AND D. M. THON, *Phys. Rev.*, Vol. 81, p. 1069 (1951).
L. R. DAVIS, H. M. CAULK AND C. Y. JOHNSON, *Phys. Rev.*, Vol. 91, p. 431 (1953).
L. GOLDFARB, H. L. BRADT AND B. PETERS, *Phys. Rev.*, Vol. 77, p. 751 (1950).
J. LINSLEY, *Phys. Rev.*, Vol. 93, p. 899 (1954).
G. J. PERLOW, L. R. DAVIS, C. W. KISSINGER AND J. D. SHIPMAN, JR., *Phys. Rev.*, Vol. 88, p. 321 (1952).
G. W. MCCLURE, to be published.

[b] The threshold energy was determined by the Čerenkov detector rather than by the earth's magnetic field.
[c] The lower value is defined by the Sotrmer cone plus earth's shadow cone, the upper by the main cone.

have revealed that the splash albedo flux at an atmospheric depth of 18.5 g. cm.$^{-2}$ constitutes about 15 per cent of the total intensity at $\lambda = 10°$. If sufficient information were available to take into account the appropriate modification of ρ, the alpha-particle flux determined by the integral method might be *increased*.

3. Air Showers

The obvious effect of air showers would be in the direction of increasing the number of observed events attributed to alpha particles in any specific altitude interval.

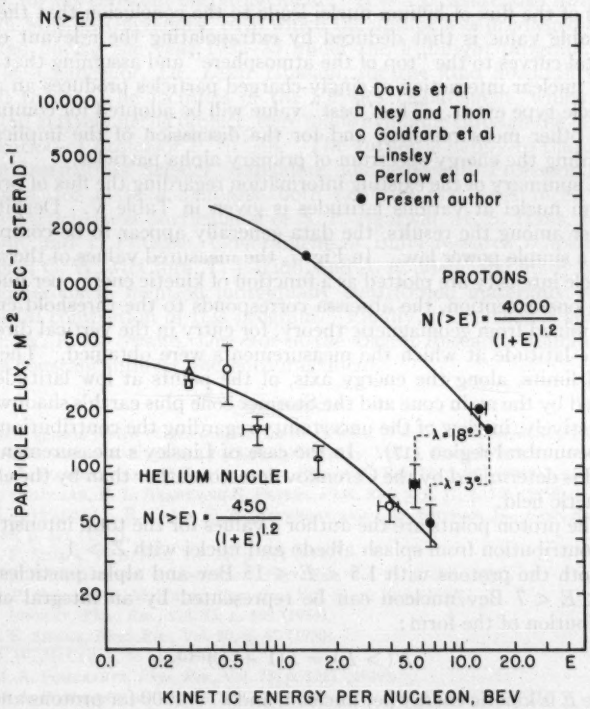

FIG. 7. Dependence upon threshold energy of the flux of primary protons and helium nuclei respectively. The curves represent integral energy distributions of the form $N(>E) = k(1+E)^{-1.2}$ where E is kinetic energy per nucleon, and $k = 4000$ for protons, 450 for helium nuclei.

However, cascade showers attain a maximum within the atmosphere in accordance with the well-known transition curve. Over the range encompassed by Fig. 6, the air-shower intensity undoubtedly increases as a function of atmospheric pressure. Thus, if the appropriate corrections were applied, the slope of the $N(I > 3.2I_{\min})$ curve might be steeper than the plotted line. This could result in an even *larger* extra-

polated value for N_2, and hence the alpha-particle flux determined therefrom would be *increased.*

B. Spectral Energy Distribution

An evaluation of all of the factors involved in the present determinations of the flux of helium nuclei leads to the conclusion that the most probable value is that deduced by extrapolating the relevant experimental curves to the "top of the atmosphere" and assuming that every local nuclear interaction of singly-charged particles produces an alpha-particle type event. This "best" value will be adopted for comparison with other measurements, and for the discussion of the implications regarding the energy spectrum of primary alpha particles.

A summary of the existing information regarding the flux of primary helium nuclei at various latitudes is given in Table V. Despite the scatter among the results, the data generally appear to be compatible with a simple power law. In Fig. 7, the measured values of the alpha-particle intensity are plotted as a function of kinetic energy per nucleon. With one exception, the abscissa corresponds to the threshold energy, determined from geomagnetic theory, for entry in the vertical direction at the latitude at which the measurements were obtained. The indicated limits, along the energy axis, of the points at low latitudes are defined by the main cone and the Stormer cone plus earth's shadow cone respectively, in view of the uncertainty regarding the contribution from the penumbral region (17). In the case of Linsley's measurement, the cutoff is determined by the Čerenkov detector rather than by the earth's magnetic field.

The proton points are the author's values for the total intensity less the contribution from splash albedo and nuclei with $Z > 1$.

Both the protons with $1.5 < E < 15$ Bev and alpha particles with $0.3 < E < 7$ Bev/nucleon can be represented by an integral energy distribution of the form:

$$N(> E) = k(1 + E)^{-1.2} \tag{9}$$

where E is kinetic energy per nucleon, and $k = 4000$ for protons and 450 for alpha particles. The available data relating to the heavier primaries in this energy interval likewise appear to be consistent with the same power-law relationship, indicating that the velocity spectra of all the primary cosmic rays are the same, independent of atomic number.

The anomaly in the total intensity at $\lambda = 18°$ in India has already been discussed (17). It is interesting to note (see Table III) that, within the experimental uncertainties, the ratio $N(I > 3.2I_{\text{min}})/N_{\text{total}}$ is constant between 3° N and 18° N, revealing that the composition of the primary cosmic radiation is not drastically different at these two stations. Thus, as is indicated in Fig. 7, the enhanced intensity at $\lambda = 18°$ does not appear to be attributable predominantly to a single component.

Acknowledgments

The author wishes to express his gratitude to the National Geographic Society for its continuing support in sponsoring the India Expedition, and to Dr. Lyman J. Briggs, Chairman of the Research Committee, for his constant encouragement. It is a pleasure also to thank Aligarh Muslim University, with which the author was privileged to be affiliated during the year 1952–53 under the Fulbright program, and the Vice-Chancellor, Dr. Zakir Hussain, for the kind hospitality extended to us. The facilities of the Physics Department, which participated actively in the project, were made available through the helpful cooperation of Professor P. S. Gill. The author is happy to thank the Indian Institute of Science, Bangalore, and especially Professor R. S. Krishnan, for making available both facilities and assistance. The active participation particularly of S. P. Agarwal, H. S. Hans, R. N. Mathur, and J. Prakash, Government of India research scholars, as well as of G. W. McClure, T. J. Tidd, and A. E. Viele, and many others too numerous to mention individually contributed materially to the successful completion of this program. Finally, the author is grateful to Dr. W. F. G. Swann, Director of the Bartol Research Foundation, for his constant interest and encouragement.

REFERENCES

(1) For a general review of this subject, see B. PETERS, "Progress in Cosmic-Ray Physics," Amsterdam, North Holland Publishing Company, Vol. 1, Chap. IV, 1952.
(2) M. A. POMERANTZ AND F. L. HEREFORD, *Phys. Rev.*, Vol. 76, p. 997 (1949).
(3) L. GOLDFARB, H. L. BRADT AND B. PETERS, *Phys. Rev.*, Vol. 77, p. 751 (1950).
(4) G. J. PERLOW, L. R. DAVIS, C. W. KISSINGER AND J. D. SHIPMAN, JR., *Phys. Rev.*, Vol. 88, p. 321 (1952).
(5) S. F. SINGER, *Phys. Rev.*, Vol. 76, p. 701 (1949).
(6) J. R. WINCKLER AND K. ANDERSON, *Phys. Rev.*, Vol. 93, p. 596 (1954).
(7) E. P. NEY AND D. M. THON, *Phys. Rev.*, Vol. 81, p. 1069 (1951).
(8) J. LINSLEY, *Phys. Rev.*, Vol. 93, p. 899 (1954).
(9) S. F. SINGER, *Phys. Rev.*, Vol. 80, p. 47 (1950).
(10) G. W. MCCLURE, to be published.
(11) M. A. POMERANTZ, *Phys. Rev.*, Vol. 75, p. 1721 (1949).
(12) M. A. POMERANTZ AND G. W. MCCLURE, *Phys. Rev.*, Vol. 86, p. 536 (1952).
(13) M. A. POMERANTZ, *Electronics*, Vol. 24, p. 88 (1951).
(14) G. W. MCCLURE, *Phys. Rev.*, Vol. 87, p. 680 (1952).
(15) L. LANDAU, *J. Phys. USSR*, Vol. 8, p. 201 (1944).
(16) K. R. SYMON, Thesis, Harvard University, 1948, unpublished.
(17) M. A. POMERANTZ, *Phys. Rev.*, Vol. 95, p. 531 (1954).
(18) K. ANDERSON (private communication). The author wishes to thank Dr. Anderson for making his results available prior to publication.

"Color Equalizer" for Television.—The Radio Corporation of America recently announced the invention of a magnetic field equalizer called the "Color Equalizer." This is a significant new RCA invention which guarantees improved color set performance and makes possible a reduction in manufacturing costs.

Dr. E. W. Engstrom, Executive Vice President, RCA Research and Engineering, pointed out that, previously, the performance of color tubes was affected by magnetic fields such as the earth's field or local sources. "To minimize such disturbances," Dr. Engstrom said, "tubes have been protected up to now with a conical magnetic shield which was effective in shielding the small end of the tube cone, but relatively less effective near the tube face. We have also used a rim coil in the form of a loop placed near the plane of the phosphor plate, in addition to the magnetic shield.

"Our new 'Color Equalizer' performs the function of the rim coil, but unlike the rim coil, its effects may be controlled at various points around the circumference of the color tube face. It makes unnecessary either a magnetic shield or the rim coil. The net result is a better, more positive effect and a reduction in cost of the receiver.

"The magnetic shield has been an item of relatively high cost in a color receiver even though we have carried on an active cost reduction development. We now propose to use the new RCA 'Color Equalizer' in place of the magnetic shield and the rim coil formerly used. By doing so, a saving will be effected in the cost of manufacturing our new 21-in. color receiver. In indicating this saving we are comparing the use of the lowest cost magnetic shield we have been able to develop for our 19-in. glass envelope color tube together with a rim coil, and the 'Color Equalizer' for use with our 21-in. metal envelope color tube. The saving on this item alone represents a saving to the consumer of at least $20."

Rhodium for Jewelry Plating (*White Metal News Letter*, Vol. XIX, No. 3).—Much of the popular costume jewelry is given a "flash" plating of rhodium, a metal of the rare platinum group. Most applications of rhodium for this purpose are a very thin electrodeposit within the range of one-hundred thousandth to one millionth of an inch thick. This coating of rhodium provides a hard and highly reflective surface.

Rubber Roads.—"Stretching a road from here to there" may be more than just a figure of speech, that is, if "rubber" roads become widespread. Tiny pellets, about the size of pencil erasers, which mix easily with asphalt without having to be shipped hot in insulated tank cars, may make possible more durable roads while cutting costs appreciably. Both the synthetic rubber pellets and the petroleum asphalt owe a large part of their existence to oil. Among the good qualities attributed to the "rubber" roads are elasticity that makes them better able to withstand rigors of traffic and heavy loads, a lack of softness in summer or cracking in winter.

Safe Refrigerant.—A new refrigerant has been developed which offers safety in cooling to 150 F. below zero, yet is nonexplosive and nonflammable. Bearing the complicated name of monochlorotrifluoromethane and derived in part from oil, the new refrigerant is expected to fill the bulk of present industry low-temperature requirements, and be useful in chemical and pharmaceutical processing, aging of steel, and most types of low-temperature aircraft testing work.

PHOTOMETRICS IN ASTRONOMY

BY

PARRY MOON [1] AND DOMINA EBERLE SPENCER [2]

ABSTRACT

The recent growth of astrophysics emphasizes the differences that exist between the photometric nomenclature of physics and that of astronomy. Astronomers employ such concepts as "brightness," "luminosity," and "magnitude"; but these same words are used with entirely different meanings by astronomers and by physicists. The paper shows how photometric concepts of the two groups can be correlated and made more precise.

1. INTRODUCTION

Each branch of science and technology develops concepts and units which, at their inception, seem most convenient in certain specialized calculations. Such a procedure is a natural one; and only when overlapping and interconnection of various fields occur, does this provincialism become troublesome. A familiar example is magnetic theory, which was developed independently from electric theory. Though Oersted showed in 1820 that the two subjects are interrelated, it is only within the last decade that the Giorgi mks system has freed us from the redundant sets of units that had plagued physicists for a century. Similarly, in astronomy we have "magnitude," "color index," and other ideas that are as unfamiliar to the physicist as his decibel system is to the astronomer.

The scientist is often accused of inventing an esoteric jargon that is meaningless to the uninitiated. This accusation is valid only if it places a barrier between one scientist and another. Certainly, it behooves all scientists to use the same nomenclature and employ the same units, even though the initial stages in such a unification may be burdensome.

One of the most glaring examples of poor standardization is the notation of photometrics, which has different nomenclature in astronomy, physics, meteorology, photography, and illuminating engineering. Too often attempts at standardization in this field have been left to the lighting-fixture salesman. The resulting definitions are of questionable value even for room lighting and are certainly inadequate for astrophysics.

In 1914, Herbert E. Ives published a noteworthy paper (1)[3] outlining

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[3] The boldface numbers in parentheses refer to the references appended to this paper.

a general system of radiometric and photometric concepts applicable to all of science and engineering. In the following pages, we have attempted to present a comprehensive system, somewhat similar to Ives' but taking into account the developments that have occurred during the intervening years.

2. PRINCIPAL CONCEPTS

A logical system (2) of active concepts is listed in Table I. The basic quantity may be taken as radiant power or *radiant pharos*, ex-

TABLE I.—*Principal Concepts of Radiometry and Photometry.*

RADIOMETRIC CONCEPTS				PHOTOMETRIC CONCEPTS			
Symbol	Name	Dimensions	Unit	Symbol	Name	Dimensions	Unit
F_r	Radiant pharos (radiant power)	$[P]$	watt	F	Luminous pharos (luminous flux)	$[F]$	lumen
D_r	Radiant pharosage	$[PL_t^{-2}]$	watt m^{-2}	D	Luminous pharosage	$[FL_t^{-2}]$	lumen m^{-2}
Q_r	Radiant phos	$[PT]$	watt sec	Q	Luminous phos	$[FT]$	lumen sec
U_r	Radiant phosage	$[PTL_t^{-2}]$	watt sec m^{-2}	U	Luminous phosage	$[FTL_t^{-2}]$	lumen sec m^{-2}
H_r	Radiant helios	$[PL_t^{-2}L_r^{-1}]$	herschel	H	Luminous helios	$[FL_t^{-2}L_r^{-1}]$	blondel
G_r	Radiant heliosent	$[PL_t^{-2}L_r]$	herschel m^{-1}	G	Luminous heliosent	$[FL_t^{-2}L_r]$	blondel m^{-1}
$J(\lambda)$	Phengosage	$[PL_t^{-2}\Delta^{-1}]$	watt m^{-2} micron^{-1}				

$\bar{y}(\lambda)$ Spectral lamprosity

pressed in *watts*. The quantity measured by bolometer or radiation thermocouple is *radiant pharosage*,[4] which is defined as radiant power per unit area. The mks (meter-kilogram-second) system of units is used, in accordance with modern trends in physics and electrical engineering (3).

Helios and *heliosent* are useful in the consideration of scattering and absorbing media; in the earth's atmosphere, for instance, or in the astrophysics of stellar interiors. The helios, at a point P in space and in a given direction, is defined as π times the pharosage at P, per unit solid angle (4):

$$H_r = \pi \lim_{\Omega \to 0} \frac{D_r}{\Omega} \tag{1}$$

where Ω is the solid angle whose apex is at P and whose axis is in the given direction. *Heliosent* is the helios contributed by a radiating medium, per unit thickness:

$$G_r = \frac{dH_r}{dl}. \tag{2}$$

Helios and heliosent are scalar functions of position and direction; but pharosage may be considered, if desired, as a vector, thus allowing the use of vector field theory (5).

[4] Pronounced *far o sazh'*. The *-age* ending indicates "per unit area," just as *-ent* means "per unit distance," *-or* indicates a device, and *-ance* indicates a property of a device.

Physical measurements ordinarily deal with power rather than with energy. Thus it is convenient to employ radiant pharos F_r and the geometrically related concepts D_r, H_r, and G_r. In some cases, however, the use of energy may be desirable instead of power. Then *phos* and *phosage* are used.

A radiation thermocouple or a bolometer placed at the exit slit of a monochromator allows the measurement of radiant pharos per unit wavelength band. This characteristic of a continuous spectrum may be called the *phengosage* $J(\lambda)$ and may be expressed in watt m^{-2} micron^{-1}. The total pharosage is

$$D_r = \int_0^\infty J(\lambda)d\lambda. \tag{3}$$

This completes our brief survey of radiometric concepts. If a selective receptor (the eye, the photocell, or the photographic plate) is employed instead of a non-selective receptor, the values of $J(\lambda)$ must be weighted with respect to a response function $w(\lambda)$ for the particular receptor (6). Then, in place of Eq. 3, we have for the total response:

$$D = \int_0^\infty w(\lambda) \cdot J(\lambda)d\lambda. \tag{4}$$

Here D can no longer be expressed in watt m^{-2}: it requires a new unit for each weighting function.

If $w(\lambda)$ represents the response curve for a photocell (amperes per watt m^{-2}), then D is the current (amp.) produced by the cell. If $w(\lambda)$ represents the relative sensitivity of a photographic emulsion, then D expresses the radiation evaluated with respect to this receptor. But the most useful weighting function is the one for the light-adapted eye (7) (C.I.E. lamprosity function $\bar{y}(\lambda)$). When this internationally standardized weighting function is used in Eq. 4, D is called *luminous pharosage* ("luminous flux density," "illumination"), which may be taken as the basis for a whole set of *photometric concepts* (Table I).

Note the close parallelism between radiometric and photometric columns of Table I. The same symbols are employed in both columns, with subscripts r and l to distinguish between radiometric and photometric quantities. When we are dealing with a single system, subscripts can be omitted without ambiguity. Also, the names of concepts are the same in both columns, except for the adjectives "radiant" and "luminous." Dimensions are also parallel, one set being based on radiant pharos $[P]$ and the other on luminous pharos $[F]$. Two distance dimensions—radial $[L_r]$ and tangential $[L_t]$—are needed to make the specification unique (8).

By employing Eq. 4 with other weighting functions, we can derive various sets of concepts parallel to those of Table I. The use of an average curve $w(\lambda)$, for a type of photographic plate commonly used in

astronomy, gives photographic concepts F_p, D_p, Q_p, U_p, H_p, and G_p. Another set of concepts utilizes the curve for the dark-adapted eye (rod vision), which gives quantities suitable for work with large, dark objects at very low values of helios (9).

In the visual observation of stars, satisfactory results are obtained most frequently when the star is imaged on the fovea. And the fovea contains no rods. Thus the weighting function for cone vision should be useful in astronomy. Apparently the C.I.E. weighting function is satisfactory here, just as it is in so many other applications of light. The systems of Table I therefore remain the two most important of the many possible parallel systems. Even *photographic* measurements can be made in terms of lumens by the use of panchromatic plates with green filters; and suitable filters allow *photocells* also to be corrected to the lumen basis. It would seem that astronomers might simplify their calculations by the more frequent use of color-corrected photography, thereby eliminating "photographic magnitudes."

Examination of Table I shows that our nomenclature is not in complete agreement with any of the systems developed by illuminating engineers (10). The purpose of our study (2), extending over a period of 16 years, has been to develop a nomenclature that is completely general so that it can be employed in all calculations of light (11). Advantages are

(*a*) Maximum generality. Elimination of specialized ideas like "candlepower" and "brightness," which are of limited applicability.

(*b*) Parallel arrangement of radiometric and photometric quantities. Can be extended to any other response curves.

(*c*) International names. Unambiguous. Can be incorporated into any language without translation (12).

3. A SIMPLIFIED SYSTEM

In most astronomical work, the full set of concepts (Table I) is not needed. In fact there is advantage in limiting ourselves, whenever possible, to

(1) Luminous pharosage D,
(2) Luminous pharos F.

Pharosage will be expressed in *lumens per square meter* and pharos in *lumens*. It is convenient to express these quantities also on a logarithmic scale.

Pharosage and pharos meet the two most frequent needs in astronomical photometrics:

(1) the need for a measure of the light received on the earth from a star, and
(2) the need for a measure of the intrinsic strength of the source.

The first need is met by specifying the incident lumens per square meter

received at the earth from the given star. The value is measured on a surface that is perpendicular to the direction of propagation of radiant energy; and this value should be corrected for the effect of the earth's atmosphere. Then D represents the true luminous pharosage outside the atmosphere, independent of atmospheric conditions, elevation of the observatory, or zenith angle of the star. The quantity which we call *pharosage* is usually called "brightness" by astronomers. Such a use of the term "brightness" is unfortunate, since it is completely at variance with accepted meanings (10).

Experience shows that logarithmic quantities are useful in astronomical calculations. Pharosage can be expressed logarithmically, giving *magnitude* m. According to Russell (13),

$$m = -2.500 \log D - 14.18, \tag{5}$$

where D is the incident pharosage in lumen m^{-2}. The difference in magnitude of two stars is therefore

$$m_1 - m_2 = 2.500 \log (D_2/D_1). \tag{6}$$

Also, from Eq. 5, the pharosage corresponding to a given magnitude is

$$D = 2.128 \times 10^{-6}(10)^{-0.400m}. \tag{7}$$

It is interesting to compare the concept of stellar magnitude with a logarithmic relation that has become important in acoustics and electricity. The *decibel* difference between two values of pharosage is defined as

$$(D_1)_{db} - (D_2)_{db} = 10 \log (D_1/D_2). \tag{8}$$

The zero of the decibel scale can be placed anywhere; but a convenient location is at the absolute threshold of the eye. Taking threshold pharosage as

$$D_{\min} = 6.78 \times 10^{-9} \text{ lumen m}^{-2},$$

and atmospheric transmission as 0.80, we have as decibel specification of pharosage:

$$(D)_{db} = 10 \log D + 80.73. \tag{5a}$$

Also,

$$D = 8.45 \times 10^{-9}(10)^{0.1(D)_{db}}. \tag{7a}$$

Comparison of Eqs. 5 and 5*a* shows that

(*i*) The scales of magnitude and decibels run in opposite directions. A large magnitude is associated with small pharosage: a large decibel value means large pharosage.

(*ii*) Each step in the decibel scale is exactly one-quarter of a step in

the magnitude scale. Thus *a difference of one magnitude is exactly equal to a difference of 4.00 decibels.* The conversion factor is

$$(D)_{db} = 24.0 - 4.00m. \tag{9}$$

Some values of $(D)_{db}$ and m are listed in Table II.

TABLE II.—*Some Conspicuous Stars.*

(Values apply outside the earth's atmosphere)

Name	D (lumen m^{-2})	$(D)_{db}$	m
Sun	1.29×10^{5}	131.8	−26.96
α Canis Majoris	9.12×10^{-6}	30.3	−1.58
α Lyrae	1.87×10^{-6}	23.4	+0.14
α Boötis	1.71×10^{-6}	23.0	0.24
α Eridani	1.22×10^{-6}	21.6	0.60
β Centauri	9.64×10^{-7}	20.6	0.86
α Aquilae	9.38×10^{-7}	20.4	0.89
β Geminorum	6.98×10^{-7}	19.2	1.21
α Cygni	6.25×10^{-7}	18.7	1.33
β Crucis	5.35×10^{-7}	18.0	1.50

Note—Luminous pharosage D is for a surface that is perpendicular to the light rays, at the earth but outside the earth's atmosphere.

Though the astronomer may not wish to give up such a time-honored idea as stellar magnitude, he will find that all its advantages are contained in the decibel specification; and the latter is more closely related to the other sciences. The rapidly growing use of physical photometry brings astronomy, physics, and electrical engineering ever closer together. So it becomes increasingly important that experts in all these fields learn to use the same scientific language. Table III

TABLE III.—*Range of Astronomical Photometrics.*

(Values apply outside the earth's atmosphere)

D (lumen m^{-2})	$(D)_{db}$	Magnitude m
1.29×10^{5} (Sun)	131.8	−26.96
9.12×10^{-6} (Sirius)	30.3	−1.58
1.71×10^{-6}	23.0	+0.24
8.47×10^{-7}	20.0	1.0
3.37×10^{-7}	16.0	2.0
5.35×10^{-8}	8.0	4.0
8.47×10^{-9}	0.0	6.0
2.13×10^{-10}	−16.0	10.0
2.13×10^{-2}	−36.0	15.0
8.47×10^{-15}	−60.0	21.0

indicates the range of astronomical photometrics, expressed in lumen m^{-2}, decibels, and magnitudes.

As an illustration of the use of the foregoing equations, consider the light received from the sun. The solar pharosage outside the earth's atmosphere may be taken as 129,000 lumen m^{-2}. From Eq. 5*a*, we find that the corresponding value is 131.8 db above threshold. This is analogous to the same number of db in acoustics, which specifies a painfully loud sound.

What are D and m corresponding to visual threshold? For threshold, $(D)_{db} = 0$, so from Eqs. 7*a* and 9,

$$\begin{cases} D = 8.45 \times 10^{-9} \text{ lumen m}^{-2}, \\ m = \frac{1}{4}(24.0 - 0) = 6.0. \end{cases}$$

The faintest star that can be detected photographically with a 100-in. reflector is of about the 21st magnitude. From Eq. 9, this corresponds to

$$(D)_{db} = -60$$

or 60 db below the threshold of the unaided eye. The value of pharosage, outside the earth's atmosphere, produced by a star of magnitude 21, is

$$\begin{aligned} D &= 8.45 \times 10^{-9} \, (10)^{-6.0} \\ &= 8.45 \times 10^{-15} \text{ lumen m}^{-2}. \end{aligned}$$

The second photometric requirement of astronomy is a way of specifying the intrinsic output of a star. The simplest concept that applies here seems to be *total pharos* F_s, expressed in *lumens* and based on the assumption of uniform radiation in all directions. This quantity can replace the rather vague astronomical concept called "luminosity."

The total pharos F_s from a uniform star is

$$F_s = 4\pi l^2 D, \tag{10}$$

where F_s is in *lumens*, D is in *lumen* m^{-2} outside the earth's atmosphere, and l is the distance from star to earth, measured in meters. If l is expressed in lightyears, Eq. 10 becomes

$$F_s = 1.125 \times 10^{33} l^2 D. \tag{10a}$$

A logarithmic designation may be used with F_s, just as with D. *Absolute magnitude* M is such a designation:

$$M = m + 5.00 \log (32.58/l), \tag{11}$$

where l is in lightyears. The corresponding decibel expression is

$$(F_s)_{db} = (D)_{db} + 20 \log (l/32.58), \tag{12}$$

and the relation between pharos (in db) and absolute magnitude is

$$(F_s)_{db} = 24.0 - 4.00M. \tag{13}$$

Values of pharos for a few stars are given in Table IV.

TABLE IV.—*Luminous Output.*

Name	Distance (lightyears)	F_s (lumens)	$(F_s)_{db}$	M
Sun	1.581×10^{-5}	3.63×10^{28}	5.5	+4.6
α Canis Majoris	8.8	7.92×10^{29}	18.9	+1.3
α Lyrae	26.2	1.48×10^{30}	21.6	+0.6
α Boötis	40.8	3.16×10^{30}	24.9	−0.2
α Eridani	66.5	6.15×10^{30}	27.8	−0.9
β Centauri	296	9.75×10^{31}	39.8	−4.0
α Aquilae	16.0	2.69×10^{29}	14.2	+2.4
β Geminorum	32.3	8.28×10^{29}	19.1	+1.2
α Cygni	650	3.02×10^{32}	44.7	−5.2
β Crucis	204	2.51×10^{31}	33.9	−2.5

For instance, Nova Aquilae increased from $m = 18$ on June 5, 1918 to $m = -0.5$ on June 9. Expressed in decibels this change is

$$18.5(4.00) = 74.0 \text{ db},$$

corresponding to a pharos ratio of 2.5×10^7. Using an estimated distance of 1000 lightyears, we find for the maximum luminous output of Nova Aquilae,

$$(F_s)_{db} = 26.0 + 20 \log (1000/32.58) = 55.7 \text{ db}.$$

This is about 50 db above the luminous output of the sun. Indeed,

$$(F_s)_{db} - (F_\odot)_{db} = 10 \log (F_s/F_\odot)$$
$$= 55.7 - 5.5 = 50.2 \text{ db},$$

or

$$F_s/F_\odot = 104{,}800.$$

Since $F_\odot = 3.63 \times 10^{28}$ lumen, the maximum pharos of Nova Aquilae was

$$F_s = 104{,}800(3.63 \times 10^{28}) = \mathbf{3.80 \times 10^{32}\ lumens}.$$

4. DISTANCE

Photometry is useful also in the measurement of astronomical distance. For a parallax of less than about 0".010, the computed distances are so inaccurate as to be almost meaningless. The cepheids can then be employed to obtain the approximate distance. According to Shapley (**14**), the mean absolute magnitude $\bar{M}$ of a cepheid is related to its period by the empirical equation,

$$\bar{M} = -0.28 - 1.74 \log \tau, \tag{14}$$

where τ is the period in days. The distance (lightyears) is then

$$l = 32.58(10)^{0.200(\bar{m}-\bar{M})}, \tag{15}$$

where $\bar{m}$ is the mean magnitude measured at the earth.

Expressed in decibels, we have

$$(F_s)_{db} = 25.12 + 6.96 \log \tau \tag{16}$$

and

$$l = 32.58(10)^{0.5[(F_s)_{db}-(D)_{db}]}. \tag{17}$$

For still greater distances, where the individual stars cannot be resolved and where only the galaxies can be seen, an estimate of distance can be made by considering the total pharos of a galaxy as (14)

$$(F_s)_{db} = 86.8 \text{ db}, \qquad \text{or} \qquad M = -15.2.$$

Distance can then be obtained from Eq. 15 or Eq. 17.

For example, the cepheid ζ Geminorum has a period of 10.15 days and the mean pharosage at the earth is 8.0 db above threshold. From Eq. 16,

$$(\bar{F}_s)_{db} = 25.12 + 6.96 \log 10.15 = 32.12.$$

From Eq. 17, the distance to ζ Geminorum is

$$l = 32.58(10)^{0.05[32.12-8.00]} = \mathbf{524 \text{ lightyears}}.$$

The faintest objects that can be photographed with a 100-in. telescope are approximately 60 db below threshold. Assuming that one of the objects is an average galaxy with

$$(\bar{F}_s)_{db} = 86.8,$$

we find the distance

$$l = 32.58(10)^{0.05[86.8+60.0]} = \mathbf{7.1 \times 10^8 \text{ lightyears}}.$$

TABLE V.—*A Comparison of Nomenclature.*

Physical Specification			Astronomical Specification	
D	**Pharosage**	lumen m^{-2}		"Brightness"
$(D)_{db}$	**Pharosage**	*db*	m	Magnitude
$(D)_{db} = 10 \log D + 80.73$			$m = -2.5000 \log D - 14.18$	
F_s	**Pharos**	lumen	L	"Luminosity"
$(F_s)_{db}$	**Pharos**	*db*	M	Absolute magnitude
$(F_s)_{db} = (D)_{db} + 20 \log (l/32.58)$			$M = m + 5.00 \log (32.58/l)$	

5. COLOR OF STARS

Methods of color measurement for stars are still in a very unsatisfactory state. This is understandable in view of the difficulties of spectroradiometry at low values of pharosage. Future developments of physical receptors will probably help matters; but it is quite likely that the subject can be dealt with more precisely even today.

The best system of color specification is undoubtedly the C.I.E. trichromatic system (7). The spectral distribution, $J(\lambda)$ *vs* λ, is measured for the star; and the standard weighting functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are employed, giving the trichromatic specification

$$\left.\begin{aligned} X &= \int_0^\infty \bar{x}(\lambda) \cdot J(\lambda) d\lambda, \\ Y &= \int_0^\infty \bar{y}(\lambda) \cdot J(\lambda) d\lambda, \\ Z &= \int_0^\infty \bar{z}(\lambda) \cdot J(\lambda) d\lambda. \end{aligned}\right\} \tag{18}$$

These integrated values can be obtained analytically from the $J(\lambda)$-curve, or they can be measured directly by employing three calibrated filters with photocells or with photographic plates. The latter method (trichromatic colorimeter) requires no spectroradiometer and is therefore suitable for stellar measurements.

The three numbers (X, Y, Z), obtained in either way, may be regarded as the coordinates of a point in color 3-space. Useful also are the homogeneous coordinates in a color 2-space:

$$\left.\begin{aligned} x &= \frac{X}{X+Y+Z}, \\ y &= \frac{Y}{X+Y+Z}. \end{aligned}\right\} \tag{19}$$

Each quality of color is uniquely represented by a distinct point in the color triangle.

The advantage of the C.I.E. system is that it applies to any radiator and is not limited to non-selective or Planckian radiation. If the radiation is really Planckian, points lie on a single curve (Planckian locus) in the color diagram, and specification requires only one number instead of two. This number is usually taken as the *temperature*. But spectroradiometric curves for the sun and for some stars exhibit rather large deviations from a Planckian curve. Thus the designation of star color by temperature is a rather crude approximation which should preferably be replaced by the trichromatic specification.

Color temperature T_c is usually determined from visual and photographic magnitudes or from visual and bolometric magnitudes. Probably a more accurate determination can be made by using one receptor with two colored filters, say a red and a blue. The ratio of readings obtained with the two filters is a function of color temperature, and the calibration can be effected experimentally by means of a color-temperature standard lamp or can be calculated on the basis of Planck's equation. All these methods, however, suffer from the defect that a non-selective radiator is postulated. It is not surprising, therefore, that experimental values, obtained for a given star by different methods, often differ by a thousand degrees. Would it not be preferable to replace the two filters of the T_c-determination by *three* filters required for the trichromatic method, thus obtaining a true specification of color without assumption of blackbody radiation?

REFERENCES

(1) H. E. IVES, "The Units and Nomenclature of Radiation and Illumination," *Astrophys. J.*, Vol. 45, p. 39 (1917).

(2) P. MOON AND D. E. SPENCER, "Photometrics in General Physics," *Am. J. Phys.*, Vol. 11, p. 200 (1943); "A Proposed International Photometric System," *Am. J. Phys.*, Vol. 14, p. 431 (1946); "Comparison of Photometric Systems," *Am. J. Phys.*, Vol. 15, p. 84 (1947); "A Study of Photometric Nomenclature," *J. Opt. Soc. Am.*, Vol. 36, p. 666 (1946); "Brightness and Helios," *Illum. Eng.*, Vol. 39, p. 507 (1944); "Brillo y Helios," *Revista Electrotecnica*, Vol. 32, p. 333 (1946); "Photometric Nomencalture," *Illum. Eng.*, Vol. 42, p. 611 (1947); "Photometry," *Encyclopedia Britannica*, Vol. 17, p. 840 (1948); "Photometry," *Collier's Encyclopedia*, Vol. 16, p. 27 (1950).

(3) P. MOON AND D. E. SPENCER, "Utilizing the mks System," *Am. J. Phys.*, Vol. 16, p. 25 (1948).

(4) P. MOON AND D. E. SPENCER, "Lighting Design," Cambridge, Mass., Addison-Wesley Press, 1948, Chap. I.

(5) P. MOON AND D. E. SPENCER, "Theory of the Photic Field," JOUR. FRANKLIN INST., Vol. 255, p. 33 (1953); "Some Applications of Photic Field Theory," JOUR. FRANKLIN INST., Vol. 255, p. 113 (1953).

(6) P. MOON AND D. E. SPENCER, "Analytic Representation of Trichromatic Data," *J. Opt. Soc. Am.*, Vol. 35, p. 399 (1945); "Analytic Expressions in Photometry and Colorimetry," *J. Math. Phys.*, Vol. 25, p. 111 (1946).

(7) Commission Internationale de l'Eclairage, *Compte Rendu*, 1931 Session, Cambridge Univ. Press, p. 25 (1932).

(8) P. MOON AND D. E. SPENCER, "A Modern Approach to Dimensions," JOUR. FRANKLIN INST., Vol. 248, p. 495 (1949); "The Dimensions of Physical Concepts," *Am. J. Phys.*, Vol. 17, p. 171 (1949); "A Geometric Treatment of Dimensions in Physics," *Canadian J. Research*, Vol. 28A, p. 268 (1950).

(9) G. L. WALLS, "The Basis of Night Vision," *Illum. Eng.*, Vol. 39, p. 93 (1944).

(10) "International lighting vocabulary," Commission Internationale de l'Eclairage, Teddington, England (1938); "Illuminating Engineering Nomenlcature and Photometric Standards," *Illum. Eng.*, Vol. 36, p. 815 (1941); "Report of the Colorimetry Committee," *J. Opt. Soc. Am.*, Vol. 34, p. 246 (1944).

(11) PARRY MOON, "A System of Photometric Concepts," *J. Opt. Soc. Am.*, Vol. 32, p. 348 (1942); "The Names of Physical Concepts," *Am. J. Phys.*, Vol. 10, p. 134 (1942); "Scientific Basis of Illuminating Engineering," New York, McGraw-Hill Book Co., Inc., (1936); P. MOON AND D. E. SPENCER, "Modern Terminology for Physics," *Am. J. Phys.*, Vol. 16, p. 100 (1948).

(12) P. MOON AND D. E. SPENCER, "Internationality in the Names of Scientific Concepts: a Method of Naming Concepts," *Am. J. Phys.*, Vol. 14, p. 285 (1946); "Pri la Defino e Nomizo di Ciencala Koncepti," *Progreso*, Vol. 23, p. 13 (1947); "Languages for Science," JOUR. FRANKLIN INST., Vol. 246, p. 1 (1948); "La Latino kom Linguo Helpanta depos la Mez-epoko," *Progreso*, Vol. 25, No. 2, p. 18 (1949).

(13) H. N. RUSSELL, "The Stellar Magnitudes of Sun, Moon, and Planets," *Astrophys. J.*, Vol. 43, p. 103 (1916).

(14) H. Shapley, "Galaxies," Philadelphia, Blakiston Co., 1943, pp. 62, 157; "Galactic and Extragalactic Studies," *Proc. Nat. Acad. Sci.*, Vol. 26, p. 541 (1940).

Clean Rails for Locomotives.—Every day could be wash day somewhere on the railroads if a new theory uncovered by the General Electric Company proves economically feasible. The theory points to washing rails—with a detergent possibly—to help eliminate one of the railroads' oldest and most expensive problems—slipping of locomotive wheels.

According to J. C. Aydelott, of G. E.'s Locomotive Advance Design and Development Section, the cause of a problem as old as railroads themselves has finally been isolated and several possible remedies are now being studied.

The G-E theory, developed by R. K. Allen of the Company's Locomotive and Car Equipment Laboratory, holds that slipping is caused by an extremely thin, practically invisible layer of oil approximately one molecule thick, which spreads itself over the running band of a rail at the onset of rain or when there is dew. Despite its thinness, this "monomolecular layer" can withstand pressures so high (up to 75,000 psi.) that locomotive wheel loads ordinarily used will not break through it.

"We believe that suitable rail cleaning holds the promise of fair weather adhesion around the clock every day of the year," Mr. Aydelott said. "If a practical cleansing method can be perfected, the savings to the railroads will be tremendous."

From the earliest days of locomotives pulling trains, the slipping of locomotive wheels has been a problem. Slippery rail conditions often result in stalled trains, overspeeded traction motors, delay, and expense.

At many places on railroad track, accumulations of journal oil can be observed outside the wear band. When the rails become moist or damp, the oil spreads over the rail, pushing the water off. The result is a thin film of oil which causes slipping and often stalls crack trains traveling on grades.

Journal oil, used in the bearings of freight cars, contains some percentage of animal oils which spread rapidly over a polished surface in the presence of a small amount of water. Oxidized mineral oils seem to exhibit the same characteristics as animal oils or fish oils and spread over a polished surface in the presence of moisture.

One drop of oil in the presence of moisture has the ability to cover a surface of five square meters. If tracks were not interrupted by rail joints, this one drop would spread along the polished running part of the rail (⅝-in. wide) to form a slippery film for a distance of two miles.

Mr. Aydelott feels that if the source from which the film spreads is removed, the presence of moisture will no longer cause slipping. He pointed out that most people have experienced the oil-spreading phenomenon in driving a car on an oil-dripped highway on a rainy day. When the rain first starts, the road is extremely slick. But after the rain has been falling for a while, it isn't nearly as slippery. The steady rain has washed away most of the oil film.

It has been known since the earliest experience with railroads that rails which looked perfectly satisfactory would, with the introduction of moisture, lose adhesion. Even before the turn of the Century it was observed that if rain continued, adhesion would be restored, but no satisfactory explanation of this was offered.

Cleaning methods now under investigation, in addition to water, include detergents, solvents, open flame, and ultra violet light. If a suitable cleansing agent is found, much of the sand currently used on locomotives to improve traction on wet days can be eliminated, with the added benefit of a reduction in the drag of the train.

MEDAL DAY PROCEEDINGS AT THE FRANKLIN INSTITUTE

October 20, 1954

The annual reception, dinner, and presentation of awards, known as "Medal Day," took place at The Franklin Institute on Wednesday, October 20, 1954. The reception began at 6.30 P.M. and dinner was served at 7.10 P.M. Mr. S. Wyman Rolph, President of the Institute, presided at the dinner and presented the subsequent awards.

Reception

The usual reception preceded the dinner and was attended by approximately 390 persons. Immediately following the reception and just before dinner was served in Franklin Hall, Mr. Rolph requested the guests to face the flag above the Franklin statue while Mr. Guy Marriner, director of music at The Institute, played the National Anthem.

Invocation

The Reverend Frederick R. Griffin, D.D., Minister Emeritus, First Unitarian Church, Philadelphia, Pennsylvania, delivered the invocation.

* * *

Mr. Rolph extended thanks and appreciation to the members of the Hostess Committee of The Franklin Institute for their able assistance and for their kindness in providing the beautiful floral decorations. Dinner was then served.

Toast

Mr. Rolph: "Ladies and gentlemen! Looking down on us tonight, as it has on Medal Days past, is that heroic marble statue of the great man whose memory we would honor by our works. I propose a toast to Benjamin Franklin."

* * *

Mr. Rolph (*continued*): "Now, let us adjourn to the Lecture Hall, on the floor below, where we shall proceed with the internationally-known Medal-Awarding Ceremonies for which we have gathered tonight. There are stairs to the ground floor and Lecture Hall through the bronze gates on the far side of the hall. Elevators are just beyond these pillars. We will resume our meeting in the Lecture Hall in ten minutes."

ADJOURNMENT TO LECTURE HALL

* * *

STATED MONTHLY MEETING

MR. ROLPH: "Distinguished Guests, Members of The Franklin Institute, Ladies and Gentlemen: May I, as President of The Franklin Institute, bid you welcome to the presentation of the Medal Awards for 1954.

"Today—October 20, 1954—marks the first Stated Monthly Meeting of The Franklin Institute for this season, and the first since May 19, 1954. The minutes of the last meeting were published in the June issue of the JOURNAL OF THE FRANKLIN INSTITUTE. If there are no corrections or additions . . . (Pause) . . . I declare them approved as printed.

"According to our By-Laws, the Board of Managers may nominate a person for Honorary Membership in The Franklin Institute for election by Institute members. At its meeting on September 15th, the Board so nominated Walter A. R. Pertuch, our Librarian. Mr. Pertuch celebrated his fiftieth anniversary of employment with the Institute last month, and we would like to recognize his loyalty and conscientious service over the years. All Institute members present who are in favor of his election to Honorary Membership, please indicate by saying 'Aye.' . . . (Pause) . . . All those not in favor say 'Nay.' . . . (Pause) . . . Walter A. R. Pertuch is therefore elected an Honorary Member of The Franklin Institute."

INTRODUCTION OF FORMER MEDALISTS

MR. ROLPH: "Each year I personally look forward with great pleasure to the return of former Medalists to these ceremonies. Tonight we have among us many recipients of medals awarded in past years by The Franklin Institute. So that we may again pay brief tribute to these men, William S. Pardoe, Chairman of the Committee on Science and the Arts, will read their names and the medal each has received. As he does so, will each rise and remain standing until the roll is called. Will you withhold your applause, please, until all are standing."

PROFESSOR PARDOE: "Former Medalists with us this evening are:"

FORMER MEDALISTS ATTENDING MEDAL DAY—1954

Year	Medalist	City
	CRESSON (*Founded 1848*)	
1875	Merck & Co., Inc. represented by Per K. Frohlich, Vice-President	Rahway, New Jersey
1909	Underwood Corporation represented by Donald S. Sammis, Vice-President	New York, New York
1910	Automatic Electric Company represented by Percy G. Black, Ass't Vice-President	Chicago, Illinois

1941	United States Navy represented by Captain Ernest von Kleek	Washington, D. C.
1952	H. Birchard Taylor	Ithan, Pennsylvania
1953	William Blum	Washington, D. C.

CERTIFICATE OF MERIT (*Founded 1882*)

1902	Myron Francis Hill	Westport, Connecticut
1908	General Electric Company represented by W. H. Rademacher	Schenectady, New York
1921	Joseph S. Hepburn	Philadelphia, Pennsylvania
1942	The Goodyear Tire & Rubber Company represented by Arden E. Firestone, Secretary	Akron, Ohio
1942	John J. Grebe	Midland, Michigan
1942	Walter Larkin	Norristown, Pennsylvania
1944	Western Union Telegraph Company represented by H. P. Corwith, Vice-President	New York, New York
1951	Jean Mercier	Paris, France

LONGSTRETH (*Founded 1890*)

1900	A. J. Holman & Company represented by William K. Holman, President	Philadelphia, Pennsylvania
1902	Williams, Brown & Earle, Inc. represented by Peter Abrams, President	Philadelphia, Pennsylvania
1909	J. H. Granbery	Richmond, Virginia
1911	Joseph S. Hepburn (already standing)	Philadelphia, Pennsylvania
1915	Charles D. Young	Philadelphia, Pennsylvania
1916	The Sharples Corporation represented by L. P. Sharples, Vice-President	Philadelphia, Pennsylvania
1918	H. Jermain Creighton	Nova Scotia
1921	W. Barton Eddison	Ardsley-on-Hudson, New York
1922	Joseph F. Keller	New York, New York
1923	Harry S. Parks	Pottstown, Pennsylvania
1940	Leopold Godowsky, Jr.	Westport, Connecticut
1947	Samuel Berman	Ozone Park, New York
1948	Nicholas F. Arone	Upper Darby, Pennsylvania
1948	Raleigh J. Wise	Arlington, New Jersey

POTTS (*Founded 1906*)

1928	Eugene C. Sullivan	Corning, New York
1939	H. Jermain Creighton (already standing)	Nova Scotia
1947	Robert Kent	Aberdeen, Maryland
1948	C. A. Lovell	Summit, New Jersey
1948	David B. Parkinson	Cleveland, Ohio
1949	J. Presper Eckert	Philadelphia, Pennsylvania
1949	John W. Mauchly	Ambler, Pennsylvania

LEVY (*Founded 1923*)

1945	Rupen Eksergian	Media, Pennsylvania
1948	William Cherry	Princeton, New Jersey
1948	Jan A. Rajchman	Princeton, New Jersey

HENDERSON (*Founded 1924*)

1937	Rupen Eksergian (already standing)	Media, Pennsylvania
1948	Charles D. Young (already standing)	Philadelphia, Pennsylvania

WETHERILL (*Founded 1925*)

1934	E. Newton Harvey	Princeton, New Jersey
1941	Harold S. Black	Summit, New Jersey
1949	Thomas L. Fawick	Cleveland, Ohio
1952	Albert J. Williams, Jr.	Philadelphia, Pennsylvania

CLAMER (*Founded 1943*)

1947	E. H. Dix, Jr.	Oakmont, Pennsylvania

BALLANTINE (*Founded 1946*)

1953	David G. C. Luck	Collingswood, New Jersey

FRANKLIN (*Founded 1914*)

1953	William Francis Gibbs	New York, New York

MR. ROLPH: "Gentlemen, we are honored and glad that you returned tonight to share with us the presentation of awards for 1954. Thank you, Professor Pardoe.

"It is our custom at this time to ask Dr. Henry Butler Allen, Executive Vice-President and Secretary of the Institute, to report briefly on our activities during the foregoing year. Dr. Allen."

REPORT OF THE SECRETARY

"The Institute in 1954"

DR. ALLEN: "Mr. Rolph, Ladies and Gentlemen. Just recently I had occasion to recall the early activities of the Institute—to compare the aims of our founders with our activities today. I found that though methods have changed with the times, the objectives remain pretty steadfast.

"On March 30, 1824, 'The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts' received its charter; and in April, 1824, schools were started. In October of that same year, three hundred exhibits were accepted for display for a period of three days. The formal school classes were given up quite a few years ago, to be replaced by the modern visual form of education—lecture demonstrations and so-called 'work shops' for the young. School groups are coming in increasing numbers, not only from Philadelphia but from adjacent counties and adjoining states. The number of visitors in the past twelve months exceeded any other similar period except the year 1934 when the Museum opened.

"The past year has again brought gratifying response to our efforts to make our Museum more attractive as well as instructive. For example, now in the process of construction is a reproduction of an old-time Nickelodeon, in which will be shown some of the famous motion pictures of the past. And a revamped Periodic Table of the chemical elements has been completed and shows many of the industrial uses of the elements and their compounds.

"The Fels Planetarium shares with the rest of the Museum an increase in attendance. It has become necessary to provide more Planetarium demonstrations to accommodate the larger number of school groups. And, before leaving the Museum, I must mention our new lunch rooms, just opened, for the old and young, completely automatic.

"In the early years, classroom lectures were designed primarily for the students. The early lectures for general membership were concerned with reports on the progress of science and technology. And in these present years, similar scientific and technical lectures continue to be given for our members.

"At the very beginning, need was seen for a periodical. Technical journals were lacking in this country. To satisfy this need, and to extend the Institute's service beyond local boundaries, a prospectus was issued announcing the forthcoming publication of 'The Franklin Journal and Mechanics' Magazine.' That was in August 1825. Today, the JOURNAL OF THE FRANKLIN INSTITUTE, as it has been called since 1828, has continued to serve without interruption. It goes into 47 states and 45 foreign countries.

"Our Library was started with newspaper clippings housed in the private residence of a member. Today it contains very close to 150,000 volumes, 52,000 pamphlets, and 9400 maps. Purchases and gifts during the years have given much help to students, research workers, and manufacturers. In somewhat lighter vein, an unusual but interesting gift this past year was a collection of mechanical puzzles, many books on the subject, and, to our great satisfaction, a sum of money to continue the collection.

"Research—one of the initial objectives of our founders and carried on usefully, but by fits and starts, through the years—was re-activated some thirty years ago through the philanthropy of Henry Bartol. Nuclear physics, cosmic rays, radioactivity, among other things, continue to form the main activities of the Bartol Research Foundation, located near Swarthmore, Pa.

"Then, shortly before and during World War II, we took another step ahead by re-activating research for industry, the community, and government, here in the Institute building in town. Christened in 1946 as The Franklin Institute Laboratories for Research and Development, they are now known not only in the Philadelphia area, but throughout the country. During the past year, we have nearly doubled our research for private industry. We keep 270 technical workers busy in these Labs. New projects in Magnetic Metals Research, Catalytic Research, and Metals Research are patterned after our four-year-old National Asphalt Research Center. This summer, as the result of several disastrous explosions which occurred in our city early this year, the Philadelphia Gas Works Company, in cooperation with the City of Philadelphia and the Philadelphia Electric Company, has placed

a

project with us to study methods of detecting cavities under city streets so that remedial steps can be taken before a gas-air explosion occurs with loss of life and property. We are also excited by work toward applying atomic energy to peaceful uses which has been initiated with us by the Philadelphia Electric Company.

"One project that warms our hearts is being done under a grant from the Kellogg Foundation. It is a cane for the blind, operated by the principle of radar.

"The Biochemical Research Foundation in Newark, Delaware, of which the Institute is trustee, continues to progress in its cancer research and other bio-chemistry projects.

"Our conscientious volunteer members of the Committee on Science and the Arts, as it has been called since 1834, is tonight realizing the fruition of its efforts during the past year. This Committee started under the name 'Board of Examiners' in 1824 to fill a need for a competent and trustworthy group of unbiased men upon whom inventors could rely for impartial judgment and advice upon the merit of their work. As the usefulness of the Institute and the impartiality of its judgments were appraised, it became the custodian of several medal funds.

"At a mass meeting on February 5, 1824, when it was decided to proceed with the organization of The Franklin Institute, between four and five hundred of those present announced their readiness to become subscribing members. On September 30th of this year, our membership totalled 6852. A gratifying figure—but with plenty of room for more.

"When we opened this building in 1934, we had around a hundred employees, which was considered capacity. Today—twenty years later—we have 300. (There are 511 in all, including our adjacent Laboratory annexes.) Needless to say, this once large building now seems small. But with a fine spirit of pulling together, we are making the best of what we have—and we hope that some day in the not-too-distant future, funds will be available to enlarge our quarters.

"But like other educational institutions, we find it always difficult to meet operating costs, even though exerting every effort to pay our way, and with some most welcome help from our State. To help in this problem, our Endowment Department was re-organized in March of this year, and a concerted effort is being made to increase that source of income. For current general operating expense, we are receiving increasing help from our good 'Friends of Franklin.' This is a group of individuals and companies who, since 1938, have been chipping in each year.

"All in all, the Institute feels—not smug—but reasonably satisfied that it is on the right track in carrying out the aims and purposes of that far-sighted and progressive group of men who met in the County Court House on February 5, 1824.

"Over our front door is the inscription 'In Honor of Benjamin Franklin.' To recall that great man's wisdom, The Franklin Institute is spearheading plans for a world-wide celebration in 1956—the 250th

anniversary of Franklin's birth. This celebration, we hope, will add something to the efforts for better international understanding. We have asked Mr. Clarence L. Jordan, member of our Board of Managers and Chairman of our Special Committee on the 250th Anniversary of Franklin's Birth, to tell you briefly of our plans. Mr. Jordan."

MR. JORDAN: "Ladies and Gentlemen, Benjamin Franklin believed that man's greatest gift to man was the communication of ideas. Albert Hubbard once said of him: 'His passion was to acquire knowledge. The desire of his heart was to communicate it.' This principle, which directed Franklin's life, will be the theme of the International Celebration of the 250th Anniversary of his Birth in 1956.

"More than two hundred different Societies and Institutions in twelve countries will cooperate in an exchange of ideas to help promote better international understanding. The plan might be called the first voluntarily organized world-wide forum, using the magnificent communications available today.

"Each of these Sponsoring Groups will select its own subject from four fields in which Benjamin Franklin made outstanding contributions: (1) Science—Man and Matter; (2) Sociology—Man and Society; (3) Economics—Man and His Work; and (4) International Relations—Man and His Ideals.

"The ideas advanced will be published and broadcast through the generous cooperation of the great publishing and broadcasting associations. In this way, millions of people in their own homes, in their own countries, may share in the Celebration.

"We are following a program which Benjamin Franklin himself developed. The Second Continental Congress authorized Franklin to create a plan to communicate with people in other nations, so they might know and understand our infant country.

"Franklin believed this could be done best by a non-political exchange of ideas of benefit to mankind. He wrote hundreds of papers and letters to be read and published by friends in twenty four of the great scientific and educational societies of his day. In turn, these societies sent him their ideas to spread among the eager minds of our young nation.

"The effectiveness of this work was beyond calculation. Lord Rayleigh, President of The Royal Society in 1906, said: 'Had the intense and steadfast genius of Franklin and his small band of American Philosophers been permitted to find undisturbed satisfaction in the affairs of the mind, the rise and rapid advance of American Science might ' ave been antedated by a century.'

"No one questions that the voluntary exchange of ideas has brought untold benefits to mankind. It has helped to raise standards of living, lengthened the enjoyment of life, multiplied the produce of agriculture and raised the dignity of the individual.

"What Franklin and his contemporaries once did in an era of slow and difficult communications is even more practical today with the miracles of modern publishing, broadcasting and transportation.

"In a letter to Sir Joseph Banks, Franklin emphasized the practical advantages of creating better understanding among people. He wrote: 'What vast additions to the conveniences and comforts of living might Mankind have acquired, if the money spent in wars had been employed in works of public utility.'

"Members of the Sponsoring Groups will develop this theme in a very practical, non-political manner: They will tell of great new scienfic inventions, now in the laboratories of all countries, which could benefit people more rapidly under better conditions of international cooperation; they will speak of the challenging future of atomic energy, once it may be dedicated to the service of man rather than his destruction; of the miraculous strides of medicine which might save many lives that are now lost needlessly; of the progress in agriculture which could help to meet the needs of rapidly growing populations and reduce the haunting fears of famine; of the growing maturity of the free mind, where belief in Religion and in individual enterprise hold the only hope for peace in the world today; and of the philosophy of Franklin himself, who tirelessly fought for respect and equality among all classes, races, colors and creeds, to the end that, some day, there might be a more enduring kinship among mankind.

"These are the subjects that scientists, editors, business men, educators and statesmen will discuss during 1956 in memory of Benjamin Franklin. They believe, as Poor Richard did, that such free discussion on a planned basis might help to speed the day when men no longer 'will be wolves to one another'—but partners in the long fight for peace and understanding.

"You, who are here tonight, can help. Copies of the Preliminary Plan are available on tables at the exits to this room. Take one if you will.

"There is no appeal for money, but for voluntary action in helping to spread the teachings of Benjamin Franklin during 1956—through speeches, company advertising, and literature, letters, articles, papers and broadcasts.

"The Plan tells you how. Our Committee hopes you will."

PRESENTATION OF AWARDS

MR. ROLPH: "Thank you, Dr. Allen and Mr. Jordan. Ladies and Gentlemen, it is our yearly custom to honor those scientists and engineers from over the world who, in the judgment of the able men of our Committee on Science and the Arts, contributed most outstandingly to the several fields of the physical sciences. As Professor Pardoe called the roll of former medalists here tonight, I was intrigued with their names

—as I am with the names of our honored medalists of this year. You will recognize names of Germanic origin, Latin, Celtic, Anglo-Saxon. I wonder if it reminds you, as it certainly does me, of that quality in scientific research and achievement which recognizes no geographic boundaries nor political affiliations. The quest for truth, for progress, goes on in all lands, is pronounced in many languages, and is as unquenchable as the sun itself. It is only fitting that a scientific institution such as The Franklin Institute should make awards to men regardless of country, for it was founded to honor a man who willingly shared his own discoveries and his knowledge with *all* men.

"As Mr. Jordan told you, we are approaching a year that, we hope, will mean much to the world. The truly international quality of Benjamin Franklin will, we think, reach its apogee during 1956. The Franklin Institute, spear-heading the Celebration, will be engaged in many activities centering in Philadelphia. As the plans unfold and are announced, we will all realize anew, I am sure, how important the man Franklin was to the world.

"Perhaps now you understand why, a few moments ago, I dwelt upon the international, or non-national, quality of scientific research and achievement which we, each year, attempt to recognize.

"I would like to pay tribute, too, to the men of the Committee on Science and the Arts of The Franklin Institute. Through the years, it has been the responsibility of this Committee to investigate thoroughly the records of many outstanding engineers and scientists. As a result of their intensive studies, and their recommendations, the awards which we have bestowed and which we again bestow tonight are respected and internationally known.

"Each Medalist is sponsored by the chairman of the sub-committee of the Committee on Science and the Arts which recommended him for the award. This sponsor will present the Medalist and read his citation."

(Mr. Rolph announced that working models descriptive of the achievements of some of the Medalists were on exhibit, until the end of the week, in the room adjacent to the lobby of Franklin Hall, and urged the guests to look at this interesting display.)

PRESENTATION OF THE LOUIS E. LEVY MEDALS
(Founded in 1923)

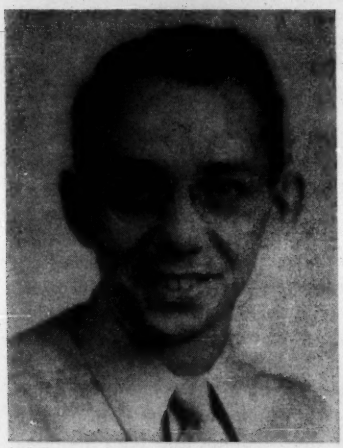
This Medal is awarded to the author, or authors, of a paper of special merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

(To Alfred C. Blaschke, Douglas Aircraft Company, Santa Monica, California and Craig L. Taylor, Professor of Engineering, University of California, Los Angeles, California.)

MR. ROLPH: "First, the Chair recognizes Dr. Joseph S. Hepburn."

DR. HEPBURN: "Mr. President, I present, *in absentia*, Alfred C. Blaschke and Craig Lee Taylor for awards.

"Their paper, published in the JOURNAL OF THE FRANKLIN INSTITUTE, presents the results of researches conducted by them in the Department of Engineering of the University of California at Los Angeles under the auspices of the Advisory Committee on Artificial Limbs of the National Research Council. It deals with the principles



ALFRED C. BLASCHKE

CRAIG L. TAYLOR

of engineering design associated with the harnessing of human muscle to operate a cineplastic prosthesis, i.e., to operate an artificial part which replaces a natural part that has been removed. By plastic surgery, a skin-lined tunnel is made in such a manner that the resulting stump may be utilized for motor purposes. The paper deals primarily with such replacement below the elbow and includes studies of the lever systems utilized for the operation of the artificial hand so as to compensate for reduction in muscle force with excursion. These researches have produced a more adaptable and acceptable prosthesis, aided in the restoration of function, and, therefore, have been of great service to the physically handicapped.

"I present, *in absentia*, Alfred C. Blaschke and Craig Lee Taylor, both of Los Angeles, California, as candidates each for a Louis E. Levy

Medal, 'In recognition of their outstanding paper, "The Mechanical Design of Muscle-Operated Arm Prostheses," appearing in the November, 1953 issue of the JOURNAL OF THE FRANKLIN INSTITUTE.'"

MR. ROLPH: "Thank you, Dr. Hepburn. The awards will be accepted by Dr. Eugene F. Murphy, their associate in the federal artificial limb program.

"By virtue of the power vested in me as President of The Franklin Institute of the State of Pennsylvania, I present, *in absentia*, to Dr. Blaschke and Dr. Taylor, these Louis E. Levy Medals and the Certificates and Reports which accompany them.

"Dr. Murphy, will you see that these Medals reach Dr. Blaschke and Dr. Taylor?"

Dr. Murphy accepted the Medals.

PRESENTATION OF THE GEORGE R. HENDERSON MEDAL
(Founded in 1924)

This Medal is awarded for meritorious inventions or discoveries in the field of Railway Engineering.

(To C. Levon Eksergian, Executive Engineer and Assistant to Vice President, The Budd Company, Philadelphia, Pennsylvania.)

C. LEVON EKSERGIAN

MR. ROLPH: "The Chair recognizes Mr. R. Thomas Sawyer."

MR. SAWYER: "Mr. President, I present C. Levon Eksergian for an award.

"The Disk Brake has been widely recognized by the American and some foreign railroads as a solution for greatly increasing both power and

energy absorption capacity in the safe operation of high-speed passenger trains. The brake was removed from the wheel to separate the functioning of the two. This allows the Disk Brake to increase its energy absorption and eliminate wheel tread damage and wear. The combination of a shoe with composite asbestos lining meeting with cast iron surface of a rotating disk gives excellent wearing properties. The shortcoming of cast iron to thermal checking has been overcome by reducing thermal stresses through design.

"The enormous heat generated during the initial period of braking at high speeds requires penetration of this heat into the disk metal with sufficient temperature gradients. This idea, as recognized in the research development of the brake by Mr. Eksergian dictated a relatively short shoe contact so that the power was concentrated to a high input per unit area thus effecting a deeper penetration into the disk for heat absorption and reducing the surface temperature. This, in turn, resulted in much higher friction and braking capacity, particularly at the higher speeds where braking is most effective. The subsequent cooling effect of the disk surface beyond the shoe contact was augmented by rotating blades between the disks thus creating a blower action, and increasing the dissipation capacity for rejecting heat on long sustained braking loads.

"The development of the Disk Brake included the design of a special cradle or frame for optimum suspension of the disks and sustaining the torque reactions on the truck, and the development of wheel slip control for maintaining maximum traction at the rail. The research also included the development of a special dynamometer and extensive road tests.

"I present C. Levon Eksergian, of Media, Pennsylvania, as a candidate for the George R. Henderson Medal, 'In recognition of his invention and subsequent intensive development and application of the Disk Brake as applied to both self-propelled and high-speed passenger cars in railroad service on this continent and to some degree abroad.'"

MR. ROLPH: "Thank you, Mr. Sawyer. Mr. Eksergian, by the same authority, I present to you this George R. Henderson Medal and the Certificate and Report which accompany it."

MR. EKSERGIAN: "Thank you."

PRESENTATION OF THE JOHN PRICE WETHERILL MEDALS
(Founded in 1925)

This Medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

(To William Donald Buckingham, Assistant Electronics Research Engineer, The Western Union Telegraph Company, Electronics Research Laboratory, Water Mill, Long Island, New York; Clarence

Nichols Hickman, Research Consultant, Jackson Heights, New York; Edwin T. Lorig, Chief Development Engineer, United States Steel Corporation, Pittsburgh, Pennsylvania.)

MR. ROLPH: "The Chair now recognizes Mr. George S. Hartman."

MR. HARTMAN: "Mr. President, I present William D. Buckingham for an award.

"The concentrated-arc lamp was developed to produce a stable, high intensity light source that could be modulated without the use of valves or shutters. The novel feature is contained in the cathode of this lamp. When installed in the lamp and properly prepared, it and the accompanying anode produce a small brilliant spot of light.

WILLIAM D. BUCKINGHAM

"The concentrated-arc lamp has an intrinsic brilliance about ten times that of conventional tungsten lamps, but slightly less brilliance than a carbon arc lamp. In addition to its brilliance and low operating temperature, its uniformity of light output and excellent color balance make it ideal for many applications. Developed during the war, it was an integral part of the aural signal lamp used for ground communications and the optical telephone used for ground to air signalling.

"I present William D. Buckingham, of Long Island, New York, as a candidate for a John Price Wetherill Medal, 'In consideration of his invention of the Zirconium Concentrated-Arc Lamp, a device capable of producing a high intensity, sharply defined, extremely small beam of light with modulation characteristics heretofore unobtainable in practical devices.'"

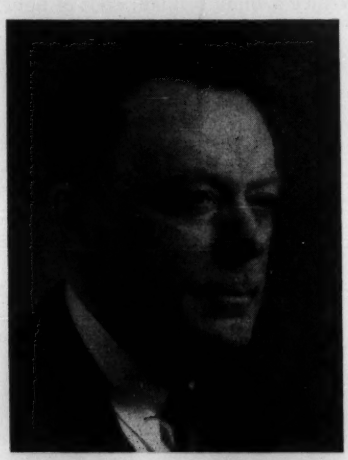
MR. ROLPH: "Thank you, Mr. Hartman. Mr. Buckingham, by the same authority, I present to you this John Price Wetherill Medal and the Certificate and Report which accompany it."

MR. BUCKINGHAM: "Thank you."

MR. ROLPH: "The Chair recognizes Dr. Thomas D. Cope."

DR. COPE: "Mr. President, I present Clarence Nichols Hickman for an award.

"From his boyhood and youth spent on the farm, in the village store, and in the country schools of Indiana, Dr. Hickman has brought to his adult years 'a rare combination of imagination, initiative, creative ability, ingenuity, manual dexterity and good critical judgment.'



CLARENCE N. HICKMAN

"These native gifts have been enriched by an education in the liberal arts at Winona College and by graduate studies which won him a doctorate in physical science from Clark University. Dr. Hickman has worked in many significant enterprises and in a number of fields. In each he has proved to be 'a prolific inventor and a skilled designer'; 'an . . . ingenious engineer with a thorough knowledge of fundamental physical principles.'

"I present Clarence Nichols Hickman, of Jackson Heights, New York, as a candidate for a John Price Wetherill Medal, 'In consideration of his inventions in rocketry, in telephony, in sound-recording, in archery and in other fields.'"

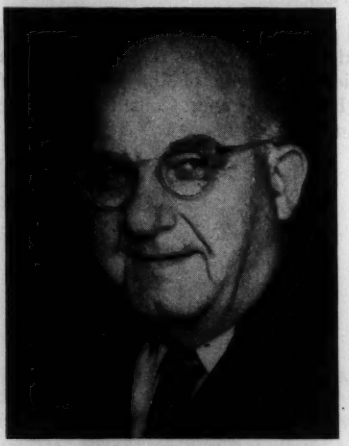
MR. ROLPH: "Thank you, Dr. Cope. Dr. Hickman, by the same authority, I present to you this John Price Wetherill Medal and the Certificate and Report which accompany it."

DR. HICKMAN: "Thank you."

MR. ROLPH: "The Chair now recognizes Mr. Sidney T. Mackenzie."

MR. MACKENZIE: "Mr. President, I present Edwin T. Lorig for an award.

"Few of us have much if any knowledge of the thousands of steps that go into the manufacture of many of the durable goods that are so common to us in this industrial age in which we live, such as the dishwasher, the washing machine, the drier, the automobile—yes, and even that container of part of our daily diet, the lowly tin can. All have included in their journey from raw material to finished product a myriad of operations. All are made from thin steel sheet. In the course of manufacture, this sheet must pass as a continuous long belt or strip over a great number of rolls or pulleys at high speed. The higher the speed, the lower the cost.



EDWIN T. LORIG

"Tonight, among others, we are here to honor a United States Steel Company engineer for his invention of a device designed to reduce the cost of those products we buy which use in their manufacture steel sheets —the washer, the automobile, the tin can.

"By application of some basic principles of physics to the invention of a new kind of roll, it was found possible to increase the speed of this strip line two and a half to three times.

"Ed Lorig, as he is familiarly known throughout the steel industry, is a steel man's steel man having spent his whole business life in that industry.

"I present Edwin T. Lorig, of Pittsburgh, Pennsylvania, as a candidate for a John Price Wetherill Medal, 'In consideration of his invention

of the Lorig-Aligner, a novel and valuable type of self-centering roll used in the rolling of steel strip and tin plate, resulting in the manufacture of a better product at a higher rate of speed and with less spoilage.'"

MR. ROLPH: "Thank you, Mr. Mackenzie. Mr. Lorig, by the same authority, I present to you this John Price Wetherill Medal and the Certificate and Report which accompany it."

MR. LORIG: "Thank you."

PRESENTATION OF THE FRANK P. BROWN MEDALS
(Founded in 1938)

This Medal is awarded to inventors for discoveries and inventions involving meritorious improvements in the building and allied industries.

(To Edmund H. Germer, Consulting Physicist, Irvington, New Jersey; Humboldt W. Leverenz, Director, Physical and Chemical Laboratory, Radio Corporation of America, RCA Laboratories, Princeton, New Jersey; Hans J. Spanner, Consultant in Electrical Engineering, Zurich, Switzerland.)

HANS J. SPANNER

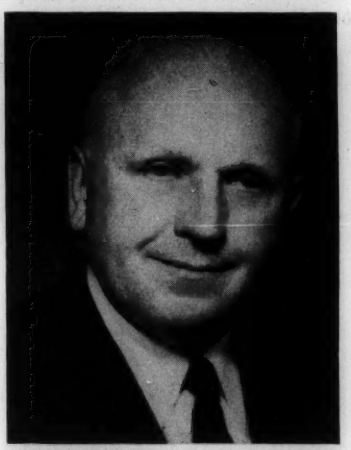
MR. ROLPH: "The Chair recognizes Mr. Joseph Gray Jackson."

MR. JACKSON: "Mr. President, I present Hans J. Spanner, *in absentia*, and Edmund Germer, who is present tonight, for awards.

"The generally used and widely popular fluorescent lamp contains mercury vapor at low pressure with an inert gas like argon for starting,

operating at ordinary commercial voltage after starting, and converting electrical input energy into ultraviolet light at the frequency of the mercury vapor resonance line and then converting the ultraviolet light to visible light by phosphors inside the tube.

"The tremendous advantage of the fluorescent lamp will be evident when we consider that a 15-watt fluorescent lamp gives as much light as a 40-watt incandescent lamp. In certain colors, the efficiency of the fluorescent lamp is actually as much as 50 to 200 times that of the incandescent lamp.



EDMUND GERMER

"The fluorescent lamp in its present conception, aside from the development of phosphors, about which you will hear in a moment, is based upon the invention of Hans J. Spanner, Edmund Germer and Friedrich Meyer, deceased. It is the result of efforts by these inventors to develop a rectifier using mercury vapor and an inert gas to make a power pack for a radio.

"I present Hans J. Spanner, *in absentia*, of Zurich, Switzerland, and Edmund Germer, of Irvington, New Jersey, as candidates for a Frank P. Brown Medal each, 'In consideration of their outstanding contribution by the development of the fundamental concept of the fluorescent electric lamp, with the accompanying benefits of high efficiency, low heat output, and wide color selection.'"

MR. ROLPH: "Thank you, Mr. Jackson. Dr. Germer, by the same authority, I present to you this Frank P. Brown Medal and the Certificate and Report which accompany it."

DR. GERMER: "Thank you."

MR. ROLPH: "By that same authority, I present to Dr. Spanner, *in absentia*, this Frank P. Brown Medal and the Certificate and Report which accompany it. Will you accept it for him, Dr. Germer?"

DR. GERMER: "Thank you."

MR. ROLPH: "The Chair recognizes Mr. Coleman Sellers, 3rd."

MR. SELLERS: "Mr. President, I present Humboldt W. Leverenz for an award.

"The Fluorescent Lamp is widely used in all types of buildings. It is three times as efficient as the incandescent lamp and operates at a much lower temperature.

HUMBOLDT LEVERENZ

"The common form consists of a glass tube containing mercury vapor at low pressure with an inert gas for starting. It converts about 50 per cent of the electrical input into ultraviolet light invisible to the human eye. This ultraviolet radiation is changed to visible light by a phosphor coating on the inside of the glass.

"Our candidate has had a large part in development of the fluorescent lamp by his years of painstaking work resulting in the discovery of new phosphors which made the fluorescent lamp a commercial possibility. One of these, the zinc beryllium silicate type, was a major contribution at the critical war period. It became the backbone of the fluorescent lamp industry, of great importance in reducing power consumption.

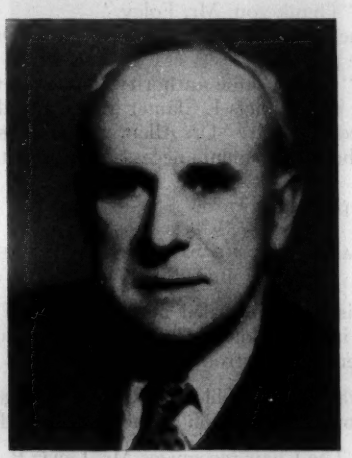
"His inventions include at least thirty-six additional phosphors and led to the development of still better phosphors used in present day lamps.

"Mr. Leverenz is the author of a text book on Luminescence of Solids, published in 1950, and many technical articles pertaining to his work.

"I present Humboldt W. Leverenz, of Princeton, New Jersey, as a candidate for a Frank P. Brown Medal, 'In consideration of his outstanding contribution to the development of the fluorescent lamp, particularly by the invention of efficient, reliable, long-lasting and versatile phosphors.'"

MR. ROLPH: "Thank you, Mr. Sellers. Mr. Leverenz, by the same authority, I present to you this Frank P. Brown Medal and the Certificate and Report which accompany it."

MR. LEVERENZ: "Thank you."



WILLIAM JUSTIN KROLL

PRESENTATION OF THE FRANCIS J. CLAMER MEDAL
(Founded in 1943)

This Medal is awarded at least once in five years for meritorious achievement in the field of Metallurgy.

(To William Justin Kroll, Consulting Metallurgist, Corvallis, Oregon.)

MR. ROLPH: "The Chair recognizes Mr. Francis B. Foley."

MR. FOLEY: "Mr. President, I present, *in absentia*, William Justin Kroll for an award.

"Many of the elements most abundant and useful to man are tied up in the earth's crust in chemical combinations so resistant to separation

that only after years of effort on the part of many researchers are they made available in useful metallic forms. This has been true of titanium, the seventh most abundant element in the earth's crust and the fourth most plentiful of the structurally useful metals. For over one hundred years, the winning of pure ductile titanium from its ores defied the efforts of the world's most accomplished investigators. It has remained for Dr. Kroll not only to succeed in producing the metal but to do so by a method readily adaptable to commercial application.

"I present, *in absentia*, William Justin Kroll, of Corvallis, Oregon, as a candidate for the Francis J. Clamer Medal, 'In recognition of his invention of a method adaptable to the large scale production of cold malleable commercially pure titanium and zirconium.'"

MR. ROLPH: "Thank you, Mr. Foley."

(Mr. Rolph then read a cable just received from Dr. Kroll regretting his inability to be present.)

MR. ROLPH: "By the same authority, I present to William Justin Kroll, *in absentia*, this Francis J. Clamer Medal and the Certificate and Report which accompany it. Dr. Allen, will you, as Secretary of the Institute, make the arrangements necessary so that the award reaches Dr. Kroll?"

Dr. Allen accepted the award.

PRESENTATION OF THE STUART BALLANTINE MEDAL
(Founded in 1946)

This Medal is to be awarded in recognition of outstanding achievement in the fields of Communication and Reconnaissance which employ electromagnetic radiation.

(To Kenneth Alva Norton, Chief of Radio Propagation Engineering Division, National Bureau of Standards, Boulder, Colorado.)

MR. ROLPH: "The Chair recognizes Mr. Lewis P. Tabor."

MR. TABOR: "Mr. President, I present Kenneth Alva Norton for an award.

"Radio and television, as sources of information and entertainment, are of enough interest and importance to most of us to make us insist on high quality and reliable reception. In order to achieve this, and to provide all necessary commercial and military services, station locations and frequency allocations must be planned in a logical and orderly manner. This in turn requires sound and accurate methods of predicting radio field strengths.

"By the integration of his careful measurements and his theoretical advances in the field of radio propagation, Mr. Norton has made available to engineers rapid and precise methods of prediction of radio field strengths and expected grades of service.

"I present Kenneth Alva Norton, of Boulder, Colorado, as a candi-

date for the Stuart Ballantine Medal, 'In consideration of his contributions over a period of twenty-five years in the field of radio propagation through which our knowledge has been considerably increased by his measurements; our insight broadened by his theoretical work; our engineering calculations made easier by his charts and our broadcasting frequency allocations above 50 mc. established more effectively through his guidance.'"

KENNETH A. NORTON

MR. ROLPH: "Thank you, Mr. Tabor. Mr. Norton, by the same authority, I present to you this Stuart Ballantine Medal and the Certificate and Report which accompany it."

MR. NORTON: "Thank you."

PRESENTATION OF THE FRANKLIN MEDAL
(Founded in 1914)

This Medal is awarded annually to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

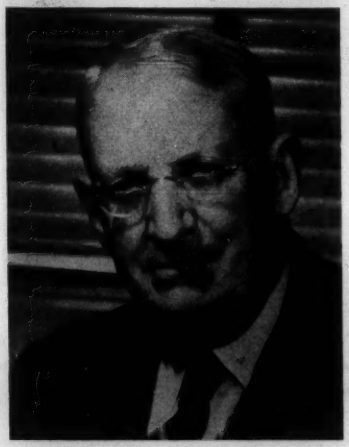
(To C. E. Kenneth Mees, Vice President in Charge of Research, Eastman Kodak Company, Rochester, New York.)

MR. ROLPH: "The Chair recognizes the final Sponsor of the evening, Dr. Nevin E. Funk."

DR. FUNK: "Mr. President, I present Charles Edward Kenneth Mees for an award.

"Dr. Mees, internationally known photographic scientist and authority on processes of color photography, has been Eastman Kodak Company's research head for forty-one years. Today he is Kodak's Vice-President in charge of Research.

"The son of a Wesleyan minister, Dr. Mees was born at Wellingborough, England, on May 26, 1882. He studied at Kingswood School, Bath; at Harrogate College, Harrogate; and at St. Dunstan's College, Catford, where he met Samuel E. Sheppard, also a student. The two formed a friendship which lasted until Sheppard's death in September 1948. They worked together at University College, London, on the theory of the photography process; and on the basis of their studies and research in this field, they received the degree of B.Sc. by research in



C. E. KENNETH MEES

1903 and of D.Sc. in 1906. Their theses, published as a book, 'Investigations on the Theory of the Photographic Process,' have since been known to workers in the field as 'Sheppard and Mees.'

"Dr. Mees spent the next six years as a partner and joint managing director of the English photographic firm, Wratten and Wainwright, Limited, of Droydon, England. During his first year there, he manufactured a successful series of panchromatic plates, light filters and darkroom safelights. He later developed special plates for photoengravers and spectroscopists and did research on the theory of photography, including the first measurements of the resolving power of photographic materials.

"In 1912, Mr. Eastman, recognizing Dr. Mees' outstanding ability in the work he had done with Wratten and Wainwright, Limited, sought his services as head of a research department which he wished to establish for the Eastman Company at Rochester. Dr. Mees felt very strongly that he was very much committed to the firm of Wratten and Wainwright and did not wish to leave it, whereupon Mr. Eastman bought Wratten and Wainwright and Dr. Mees came to Kodak Park to establish a scientific photographic laboratory and do the work in Rochester for both the American and English companies.

"The breadth of this work was great, including the areas of emulsion sensitivity, sensitometry, image structure, colorimetry, and theory of development. Later, Dr. Mees took a direct personal interest in the theory and practice of optical sensitizing of photographic emulsions and again laid the foundation for much of the successful scientific research which has since been carried out in this field.

"Due to his general guidance and, in many cases, personal direction, his Research Laboratory has perhaps contributed more to photographic science than any other organization in the world.

"During the two World Wars, the activities of the Laboratory were centered on war work.

"Mr. President, I present Charles Edward Kenneth Mees, of Rochester, New York, as a candidate for the Franklin Medal, 'For his many outstanding contributions to the scientific knowledge of the photographic process and for his development of the first organized scientific photographic laboratory in the United States which resulted in new products advancing the usefulness of the photographic process and increasing its artistic acceptance.'"

MR. ROLPH: "Thank you, Dr. Funk. By the authority vested in me as President of The Franklin Institute of the State of Pennsylvania, I present to you, Dr. Mees, this Franklin Medal with its accompanying Certificate and Report."

DR. MEES: "Thank you."

MR. ROLPH: "Ordinarily at this time we also present our Franklin Medalist with a Certificate of Honorary Membership in the Institute. However, in 1938 Dr. Mees was elected to Honorary Membership in recognition of his outstanding participation in the ceremonies of the dedication of the Benjamin Franklin Memorial.

"Ladies and Gentlemen, I doubt very much if anyone in this Lecture Hall does not personally own a camera, have access to one, or has at some time used one. Whether it be an inexpensive Brownie or an expensive, complex collection of lenses, diaphragms and shutters, they all operate by roughly the same principle. The photographic process of recording on a sensitive emulsion-coated piece of paper is one that required years of research and years of personal dedication before we could go out on a Sunday afternoon and bring back the scenes we wanted

to remember. Although the subject of Dr. Mees' talk has been listed on the program as 'The Science of Photography,' he feels that 'Fifty Years of Photographic Research' would be more descriptive. Whatever the title, I know we'll enjoy what he has to say. Dr. Mees."

ADDRESS BY C. E. KENNETH MEES

(See following page of this JOURNAL for the text of Dr. Mees' address.)

* * *

After Dr. Mees had delivered his talk, Mr. Rolph conveyed to him the thanks of the Institute, dismissed the assembly with a cordial word and declared the meeting adjourned.

FIFTY YEARS OF PHOTOGRAPHIC RESEARCH *

BY

C. E. KENNETH MEES [1]

The citation which accompanies the presentation of the Franklin Medal this evening states that the medal is awarded for contributions to the scientific knowledge of the photographic process and for the development of a laboratory resulting in new photographic products. It seems to me that you might be interested in knowing how I came to devote myself to the study of the science of photography and to the direction of a laboratory of industrial research in the field of photography.

In 1900 I went to University College, London, as a student of chemistry under that great teacher and discoverer, Sir William Ramsay. I had come from a technical school, St. Dunstan's College, Catford, and another St. Dunstan's student and friend, S. E. Sheppard, had come with me. As Sheppard and I traveled together to University College, we discussed the work that was going on around us in the laboratory and the advances being made in physical chemistry. For some time I had been interested in photography. I had started to take photographs because I was unable to draw, and I wanted to illustrate in my notebooks the chemical apparatus that I was using. Whenever we discussed photography, we were impressed by the fact that we could find no satisfactory explanation of the photographic process in any of the chemical textbooks, nor when we turned to the photographic literature did we obtain much help. We wanted to know what happened to silver bromide when it was exposed to light, what it was that made it developable—particularly, being chemists, what happened during development, and what the factors were that controlled the rate of development. Before long Sheppard found a paper in the *Journal of the Society of Chemical Industry* published in 1890 by the physical chemist in charge of the laboratory of the United Alkali Company, Ferdinand Hurter, and an associate of his in the same company, V. C. Driffield. This paper, which we afterwards found was well known in the photographic world, and which was entitled "Photochemical Investigations and a New Method of Determination of the Sensitiveness of Photographic Plates," came as a revelation. Here were people who had really studied photography scientifically. They had found a way of measuring the amount of image produced by exposure to light followed by development and of measuring the rate of development of the exposed image, so that in the work of Hurter and Driffield we had a model for an attack on the nature of the photographic process.

The apparatus that Hurter and Driffield had used was distinctly primitive, and with the advances that had taken place in physical

* Delivered at the 1954 Medal Day Meeting, October 20, 1954, in acceptance of the Franklin Medal.

[1] Vice President in charge of Research, Eastman Kodak Co., Rochester, N. Y.

chemistry since 1890 we believed that we could improve on their experimental methods and repeat their work with such improvements in the apparatus as we could achieve. Professor Ramsay was enthusiastic about such a program, and he arranged for Sheppard and me to start work on the subject and to present the work to the University of London in the form of theses as part of the requirements for the B.Sc. degree.

We erected our apparatus in the chemical laboratory at University College. As a standard, we adopted an acetylene burner light source supplied by a generator and one day had an explosion which has ever since given me a great respect for acetylene! Our primitive thermostats were made out of zinc pails, and to measure our densities we borrowed a Hüfner spectrophotometer from Professor Starling, the great professor of physiology at University College. We understood that he himself had borrowed it from Guy's Hospital, and beyond that we didn't inquire! With the more modern instruments, we laboriously repeated a good deal of Hurter and Driffield's published work and found that their equations for the growth of density during development could be applied to the increase of contrast. In 1903 Sheppard and I published two papers in the *Photographic Journal* on the development factor. We submitted our theses in notebooks to the University examiners and were both awarded the degree of B.Sc. by Research.

Both Sheppard and I by then were intensely interested in the work on the theory of the photographic process and we were convinced that by pursuing it further we should get results of value. We were anxious to continue it for another three years and then submit the results as theses for the London degree of Doctor of Science.

Photographic research requires a good deal of space since, in addition to the ordinary workrooms, darkrooms are needed, and there was no room in the crowded chemical laboratories of University College. Ramsay was willing to let us work at home and to supervise our work as if we were at the college and to let us submit our theses finally as internal students. I was living with my parents at Caterham at Surrey, and in a shed in the garden I built a darkroom, paneled the shed for warmth, and then fitted up the necessary apparatus, while Sheppard put similar equipment in a room in his father's house. For the next three years we worked at home, going to University College at intervals to attend lectures and to report to Ramsay. As a result, we were able to publish in various journals a series of papers covering our work on sensitometry, on the statics and kinetics of development, on the microscopic structure of the developed image, the chemistry of fixation, and the action of oxidizing agents on the latent image. We also submitted our theses to the University examiners and were awarded D.Sc. degrees in 1906. Altogether, Sheppard and I published 11 papers between 1904 and 1907, and they were collected and published in a book, "Investigations on the Theory of the Photographic Process," in 1907.

Then we were faced with the problem of what we should do next.

Sheppard was awarded a post-graduate scholarship for two years and went to Marburg University to work as a post-doctorate student with Professor Karl Schaum, an outstanding authority in the field of photochemistry and editor of the *Zeitschrift für Wissenschaftliche Photographie.*

I discussed my future with Sir William Ramsay. Ramsay had a very clear vision of the part that science might play in industry, and though I argued with him for an academic career, he insisted that since I had worked on photographic science I must go into the photographic industry. Thus, by the time I was twenty-four years old, I had entered the two fields of work in which I have been engaged ever since—the study of the theory of the photographic process and the application of science to industry.

I started with Wratten and Wainwright Ltd., a small firm of photographic manufacturers in England who had made experimental plates for Sheppard and me, and there was successful in making new products which presented a considerable advance in photographic methods. New optical sensitizing dyes which had been made in Germany two or three years before enabled me to make commercial panchromatic plates which were much more sensitive to orange and red light than any others on the market. For use with them in the photography of colored objects, I made a series of light filters, and to this day the "Wratten" filters are standard in photographic work.

After I had been working at Wratten and Wainwright for about six years, I had a visit one day from Mr. George Eastman, whom I had met some two years previously in the United States. Later the same day, Mr. Eastman telephoned me, asking me to come to see him in London the next day, and explaining, much to my surprise, that he wanted me to go to Rochester to organize and direct a research laboratory for the Eastman Kodak Company. I went to see Mr. Eastman, and he repeated his invitation. I told him I couldn't leave Mr. Wratten because he would not be able to carry on alone, and I could therefore only accept the offer if he would buy Wratten and Wainwright Ltd. Mr. Eastman at once agreed to buy our little business, and I went to Rochester in April, 1912, to build a laboratory.

I laid out the building plans with the engineers, went back to London, and in August migrated to Rochester with my family. Mr. Wratten joined Kodak Limited, and the manufacturing processes of Wratten and Wainwright were transferred to the Harrow factory of Kodak Limited.

My reason for accepting Mr. Eastman's offer was that I was still anxious to return to the study of the theory of photography. The pressure of practical problems at Wratten and Wainwright had made scientific work difficult, and Mr. Eastman offered the very opportunity that I had always wanted. I was interested in the idea of industrial research, and I was enthusiastic about the possibility of an integrated study of the theory of the photographic process.

The Rochester laboratory got into operation at the beginning of 1913 at Kodak Park with a staff of about twenty people. It was not under the control of the factory management, nor was it intended that it should concern itself primarily with manufacturing problems. It was decided that the laboratory should set as its main objective the study of the theory of the photographic process and its application to practical photography, so that the whole work of the laboratory was based from the beginning on photographic science.

An understanding of the nature of the photographic process requires knowledge of both the chemical and physical aspects of the subject, though these often overlap. Chemical aspects include the various processes of emulsion making; the distribution of size and sensitivity among the silver halide grains (which are the operating units in exposure and development); the reaction of the grains on exposure to light, that is, the nature of the change by which the grains become developable after exposure; the nature of the development reaction; and finally the structure of the silver produced in development. The physical aspects include the relation of the image in the camera to that formed in the developed negative and, after printing, in the positive; and the microstructure of the developed image, involving such factors as graininess, sharpness, and resolution. All these fields of work have been studied in the Kodak laboratories since 1912, and work on all branches of the photographic process is still being actively pursued.

In 1942 sufficient progress had been made to enable us to incorporate in a book an account of photographic theory to date. When the book was revised this year, the twelve years that had elapsed made it necessary to rewrite the entire volume and to change about one-third of its contents! The dream that I had as a college student, that it was possible for the theory of photography to be studied by the application of the experimental methods of physical science, has been realized. At the same time, the application of this scientific work to industrial problems has enabled us to make a great deal of progress in the manufacture of photographic materials and in the development of new applications of photography.

Industrial research has succeeded not only in the Kodak Company but everywhere else. Today our industries are founded on scientific research. Laboratories and their scientific staffs are an integral part of our industrial organizations, and the success or failure of a business often depends upon the quality of its research. I must add that if the goals to which Sir William Ramsay pointed fifty years ago have been reached, the credit belongs to the large group of scientists and technologists who have done the work. I cannot name them individually but, it is their work that you are acknowledging in awarding the Franklin Medal for contributions to the scientific knowledge of the photographic process and for developments in the art of photography.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS *

DIODE AMPLIFIER

Research on application of semiconducting diodes has led to the development of a new class of amplifiers that utilizes the reverse transient phenomenon of these two-element rectifying devices. Devised by A. W. Holt of the National Bureau of Standards, the diode amplifier—using no vacuum tubes and achieving power gains up to 10 per stage—promises important application in the future design of high-speed electronic digital computers. For example, it may be used as a pulse repeater stage, in varied types of flip-flop circuits, or as a wide-band, flat-response amplifier. Because suitable diodes are now in regular production, commercial applications are practical at the present time. Future improvement in the manufacture of diodes may make the principle useful for amplification at even microwave frequencies.

The basic requirement of the diode amplifier is that it be supplied with power from an r-f source whose frequency is the same or higher than the modulating signal frequency. This requirement puts the circuit in the same category as magnetic and dielectric amplifiers.

A semiconductor diode of the germanium or silicon type has two static conditions: (1) a forward conducting state, characterized by high conductivity, and (2) a reverse conducting state, characterized by low conductivity. The forward state is achieved by applying a biasing voltage so that the anode is more positive than the cathode; the reverse state is achieved by applying voltage of opposite polarity. The forward voltage acts to create a steady supply of "carriers" of current within the semiconducting material, thus maintaining a condition of high conductivity. Carriers are not created during the reverse static state. If the voltage applied to the diode is switched quickly from forward to reverse voltage, a transient phenomenon occurs in which a large reverse current flows for an appreciable time after switching takes place, and decays until the static reverse state is reached. The transient current occurs because the carriers which were present due to the forward voltage remain available to be swept out by the application of the reverse voltage. The carriers do not remain indefinitely during a period of delay between cessation of forward voltage and application of reverse voltage; instead, their number decreases with time during this period.

Although amplification in the diode is not a continuous phenomenon, the action may be likened to the way in which amplification is obtained in a transistor. In a transistor, the emitter can be regarded as a diode

* Communicated by the Director.

existing in the forward conducting state, and the collector as a diode in the reverse state. If any of the carriers created by the forward biased diode are transported to the vicinity of the reverse biased diode, a larger current than the static current will flow in the latter diode.

Voltage on the emitter of a transistor produces current which creates carriers. These carriers change the current in the collector, which in turn changes the voltage across the collector. In the case of a junction transistor used in the common base circuit, the collector current is almost equal to the emitter current, so that power gain is effectively determined by the ratio between the forward and the reverse resistances. Thus, power gain is obtained by a transfer of current from one circuit of low impedance to another circuit of high impedance.

The diode amplifier obtains its power gain in a similar manner, except that one electrode serves as both emitter and collector, but at different times. During one-half of the cycle, the anode is more positive than the cathode, and the anode acts as the emitter of the junction transistor; during the other half-cycle, the anode acts like a collector. When it is an emitter, it injects carriers into the germanium with only a small applied forward voltage—i.e., at a low impedance level. When it is a collector, the anode withdraws these same carriers, but only by applying a much higher voltage—at a higher impedance level.

The simplest form of diode amplifier is the resistance-diode-coupled circuit, where the r-f supply, or "clock," not only acts as the power source but also as the switch which controls the two separate phases of the amplification cycle: the intake of signal power into the amplifier diode (injection of carriers) and the output of amplified power (decay of carriers).

Some circuit element which transforms voltage gain to current gain is essential to most of the circuits using the diode amplifier, because there is no average current gain in the diodes that have been used so far in the experiments performed at the Bureau. The transformer-diode-coupled circuit achieves current gain through a step-down transformer. This circuit has the disadvantage that the fly-back requirements of the inductance are satisfied only on a many-pulse basis and not on a pulse-to-pulse basis. The many-pulse average can also cause trouble in turning off the stage at the end of a train of pulses.

Further development of the diode-amplifier concept leads to the design of a complete "pulse repeater stage" for application in electronic digital computers. A circuit which satisfies the essential requirements for a computer stage is a combination of the transformer-diode-coupled amplifier and an inhibiting gate. Extra logical "or" gates may be added as desired. Delay lines may be used but can be avoided in most cases, since the carriers in the amplifier diode store information. It may be necessary, however, to use some delay lines to time accurately the inhibiting pulses.

The diode amplifier can also be used as the basis for a variety of "dynamic" flip-flop circuits—oscillators which can remain stable either in an oscillating or a non-oscillating state.

Silicon junction diodes have a much faster transient recovery than germanium junction diodes, and therefore can be used in faster circuits. In experiments carried out at the Bureau to study the usefulness of the silicon diode as a diode amplifier, a current-doubler type of flip-flop operated satisfactorily with a clock frequency of 25 megacycles; the circuit exhibited start-stop times of about 100 millimicroseconds. It should be possible to achieve much higher frequencies by using diodes with even shorter decay times. This promises to provide very fast, practical circuitry for future use in electronic computers and many other useful applications as well.

CERAMIC COATINGS FOR USE IN NUCLEAR REACTORS

To meet the increasing demand for high-temperature protection of alloys in nuclear reactors, the National Bureau of Standards has developed a ceramic coating material of extremely low thermal neutron absorption coefficient. This ceramic material is the result of an investigation involving over 200 ceramic coating mixtures which was carried out by J. C. Richmond, H. G. Lefort, C. N. Williams, and W. N. Harrison of the Bureau staff. Most promising of the materials investigated are boron-free coatings of the frit-refractory type in which a high-barium frit is combined with ceria-chromic oxides. Tests indicate that these coatings which have computed neutron absorption coefficients in the range of 0.15 to 0.50 barn, satisfactorily withstand temperatures in excess of the 1000° C. found in nuclear reactors.

The use of ceramics or metal-ceramic combinations generally offers the only alternative to the use of bare metals for shields, moderators, and fuel rods in atomic piles designed to operate at high temperatures. The nuclear property that chiefly determines the suitability of a ceramic coating for pile construction is its low absorption of neutrons when the material is placed in the path of a neutron beam. The common ceramic coating contains boron, which may be introduced as borax or as boric acid. So far as ceramic considerations are concerned, there is no objection to boron. However, this element has an unusually large neutron capture cross section. A ceramic material assigned for use as a moderator would therefore be quite unacceptable if it contained significant amounts of this element.

Early in the program a goal was established for the maximum value of the absorption coefficient of the ceramic coatings: This value should not exceed that of the alloy to which the coating was to be applied. A survey of published data of the elements indicates that the most commonly used heat resisting alloys have thermal neutron coefficients ranging from 2.5 to 20 barns. On the basis of these data, a value of three

barns appeared to be a reasonable maximum to set for the coatings, although it was considered desirable to keep the coefficient as low as practicable. The major constituents in the ceramic coatings were therefore limited to those elements having coefficients of three barns or less; minor constituents were limited to 10 barns or less.

Metallographic examination of tested and untested coated specimens revealed that some corrosion occurred beneath the coating in every case in the extended heating tests, but the amount or apparent depth of "stringer" corrosion was markedly reduced by the coating. In terms of cross sectional area of the stringers caused by corrosion, the difference between coated and uncoated specimens is much greater.

Although none of the coatings so far evaluated by the microscopic method greatly reduced the depth of *uniform* oxidation that occurs beneath the coating, the depth of *stringer* penetration was reduced from 1.55 mils on a bare specimen to a minimum of 0.65 mil under coating, and the number of stringers per inch was reduced from 228 to 20.

A series of thermal shock resistance tests was performed on coated specimens of various alloys as well. The coated specimens were heated in a furnace and then quenched by total immersion in water at room temperature. All withstood quenching from 1100 F., and the best did not fail when quenched repeatedly from 2000 F. This thermal shock treatment is much more severe than the coatings would normally be expected to encounter in service.

THE FRANKLIN INSTITUTE

MINUTES OF THE STATED MEETING

November 17, 1954

The Stated Monthly Meeting of The Franklin Institute was held on Wednesday, November 17, 1954, in the Lecture Hall. The meeting was called to order at 8:25 P.M. by the President, S. Wyman Rolph. There were approximately 185 members and guests in attendance.

The President announced that the Minutes of the October Stated Meeting would be printed in the November JOURNAL and would be submitted for approval at the next Stated Meeting.

The President condensed the Secretary's report by stating that since April 30th, 523 persons had been elected to the various classes of membership, and that total Institute membership as of October 31, 1954, was 6,859.

The President then recognized Morton Gibbons-Neff, Chairman of the Membership Committee, who introduced Frank S. Busser. Mr. Busser, after being graduated from York High School in his native York, Pennsylvania, became a shorthand writer in the law offices of the late George Harding. He prepared and prosecuted applications for patents and thus received the stimulus to study law. He was graduated *cum laude* in 1897 from the University of Pennsylvania Law School. While continuing to practice as a patent solicitor, he devoted a great deal of his time to patent litigation, finally forming the firm Busser, Smith and Harding in which he is still active. The President presented Mr. Busser with a gold key in recognition of his fifty years of continuous membership in The Franklin Institute.

The President again recognized the Chairman of the Membership Committee, who introduced C. Mahlon Kline. Upon his graduation from the Sheffield Scientific School of Yale University at the turn of the century, Mr. Kline started as a helper in the Smith, Kline & French Laboratories (which his father, the late Mahlon N Kline, helped to bring into prominence as a wholesale drug house). Mr. Kline eventually served as analytical chemist, plant manager, vice-president and president, and is now Chairman of the Board. The President presented Mr. Kline with a gold key in recognition of his fifty years of continuous membership in The Franklin Institute.

The President then introduced Walter A. R. Pertuch, who joined the staff of the Institute in September, 1904, as an errand boy and is now Librarian. "He is to all of us a good friend," said the President, "never too busy to dig into books to get the information we seek. He has contributed much toward making our Library the best in Philadelphia (at least) for technical books in the fields of pure and applied science." The President presented Mr. Pertuch with a gold watch in appreciation of his fifty years of loyal and conscientious service, and a Certificate of Honorary Membership in the Institute, bearing the citation:

> The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts by these presents certifies that Walter A. R. Pertuch has been elected to Honorary Membership in recognition of his outstanding ability as its Librarian, and of his diligent, devoted, unselfish, and courteous service, for fifty years, to the Institute, its members, its Library, and other persons whom that Library serves.
>
> Philadelphia, Pa.
> October 20, 1954

Mr. Pertuch reminisced about his fifty years with the Institute. His talk, delightfully interspersed with amusing anecdotes, will be published in the January issue of the JOURNAL.

The meeting adjourned at 9:15 P.M., the guests giving a rising round of applause in tribute to Mr. Pertuch.

HENRY B. ALLEN
Secretary

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A. M. until 5 P. M. on Mondays, Tuesdays, Thursdays, Fridays and Saturdays; 2 P. M. until 10 P. M. on Wednesdays.

RECENT ADDITIONS

AGRICULTURE

U. S. DEPARTMENT OF AGRICULTURE. A Manual on Conservation of Soil and Water. 1954.

BIBLIOGRAPHY

Bibliographic Survey of Corrosion 1945–1949. 1948–1954.

BOTANY

SMITH, GEORGE. An Introduction to Industrial Mycology. Ed. 4. 1954.

CHEMISTRY AND CHEMICAL TECHNOLOGY

GORDON, PHILIP L. AND DOLGIN, GEORGE J. Surface Coatings and Finishes. 1954.

HOGNESS, THORFIN RUSTEN AND JOHNSON, WARREN C. Qualitative Analysis and Chemical Equilibrium. Ed. 4. 1954.

PERRY, JOHN H. Chemical Business Handbook. 1954.

RUTGERS, AREND JOAN. Physical Chemistry. 1954.

SNEED, M. CANNON; MAYNARD, J. LEWIS AND BRASTED, ROBERT C. Comprehensive Inorganic Chemistry. Vol. 3. 1954.

ELECTRICITY AND ELECTRICAL ENGINEERING

BENOIST, PAUL. Télévision. 1953.

BLANC-LAPIERRE, ANDRÉ; GOUDET, G. AND LAPOSTOLLE, P. Electronique Générale. 1953.

CHINN, HOWARD A. Television Broadcasting. 1953.

KRUGMAN, LEONARD M. Fundamentals of Transistors. 1954.

LEWIS, I. A. D. AND WELLS, F. H. Millimicrosecond Pulse Technique. 1954.

MULLARD OVERSEAS LTD. Catalogue of Mullard Radio Receiving Valves and Special Electron Tubes. 1953.

FOOD

RYFF, GUALTHERUS. Spiegel und Regiment Gesundheit. 1544.

GRAPHIC ARTS

MARX, M. RICHARD. Printing with "Varigam." 1954.

MANUFACTURE

CHAMPETIER, GEORGES. Dérivés Cellulosique. Ed. 2. 1954.

ENRICK, NORBERT LLOYD. Quality Control. Ed. 2. 1954.

MATHEMATICS

BOAS, RALPH PHILIP. Entire Functions. 1954.

KEMPTHORNE, OSCAR AND OTHERS. Statistics and Mathematics in Biology. 1954.

NORTHCOTT, DOUGLAS GEOFFREY. Ideal Theory. 1953.

PETTY, WILLIAM. Political Arithmetick . . . 1691.

MECHANICAL ENGINEERING

Audel's Diesel Engine Manual. 1954.
DUBBEL, HEINRICH. Dubbels Laschenbuch für den Machinenbau. Ed. 12. 1953.
ECKERT, BRUNO. Axialkompressoren und Radialkompressoren. 1953.
HENRIOT, GEORG. Traité Theorique et Pratique des Engrenages. Vol. 2. 1950.
STAU, CARL HEINZ. Nachformeinrichtungen für Drehbänke (Kopierdrehen). 1954.

METALLURGY

PAGONIS, GEORGE A. The Light Metals Handbook. 1954.

OPTICS

PICHT, JOHANNES. Mess und Prüfmethoden der Optischen Fertigung. 1953.

PETROLEUM TECHNOLOGY

BEERSTECHER, ERNEST, JR. Petroleum Microbiology. 1954.

PHOTOGRAPHY

CARROLL, JOHN S. Photography with the Graflex "22." 1954.

PHYSICS

BERGMANN, LUDWIG. Der Ultraschall und seine Anwendung in Wissenschaft und Technik. Ed. 6. 1954.
DAUGHERTY, ROBERT LONG AND INGERSOLL, A. C. Fluid Mechanics with Engineering Applications. Ed. 5. 1954.
DÉRIBÉRÉ, MAURICE. Les Applications Pratiques des Rayons Infrarouges. Ed. 3. 1954.
GÄNGER, BERTHOLD. Der Elektrische Durchschlag von Gasen. 1953.
LAPP, RALPH E. AND ANDREWS, HOWARD L. Nuclear Radiation Physics. Ed. 2. 1954.
SEMAT, HENRY. Introduction to Atomic and Nuclear Physics. Ed. 3. 1954.
SHAPIRO, ASCHER H. Dynamics and Thermodynamics of Compressible Fluid Flow. Vol. 2. 1954.

PLASTICS

SONNEBORN, RALPH H. Fiberglas Reinforced Plastics. 1954.

RAILROADS

BROOKS, ROBERT. Electric Traction Handbook (Control). 1954.

SCIENCE

DAVY, NORMAN, ED. British Scientific Literature in the Seventeenth Century. 1954.
GARDNER, MARTIN. In the Name of Science. 1954.

SUGAR

AUGUSTIS, QUIRICUS DE. Lumen Apothecariorum. Ed. 2. 1494.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

PLYLER, EARLE K.: Infrared Measurements, Past and Present
MISHKIN, E.: Disturbances in the Induction Machine due to Broken Squirrel-Cage Rings
SWANN, W. F. G.: Shear Modulus and Viscosity Relations in Plastic Materials
KAISER, H. F.: Microtron Resonators
HEROLD, E. W.: Semiconductors and the Transistor
FORSCHER, FREDERICK: Analysis of Continuity of One Phase in a Powder Mixture of Two Phases
KU, Y. H.: Analysis of Nonlinear Systems with More than One Degree of Freedom by Means of Space Trajectories
MALIC, DRAGOMIR: The Equation of Politronic Process of Real Gases
MINORSKY, N.: On Asynchronous Action

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, NOVEMBER 17, 1954

ACTIVE FAMILY

Coe A. Boardman
Robert L. Hershey
Henry F. Pearson

ACTIVE

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James R. Barger, Jr.
Wilfred E. Bettoney
Philip Barkan
Ernest G. Beck
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Joseph L. Doan, Jr.
P. S. du Pont, III
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Konrad Gentner
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Harry Sley
Theodore Smithers
Richard Steinberg
Edgar B. Thompson
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ACTIVE NON-RESIDENT

Clarence E. Rose

NECROLOGY

William E. Anderson '43
E. N. Benson, Jr. '36
Ralph A. Downes '36
Edward E. Marbaker '17
Bevan A. Pennypacker '47
Francis Potts Witmer '34
Grahame Wood '34

TO MEMBERS AND THOSE WHO KNOW THE FRANKLIN INSTITUTE

All of us associated with The Franklin Institute are gratified by the support given by its benefactors in the past. Without their generosity our privately endowed Institute would have been unable to serve industry, the professions, and the public as it has and should.

There is still a continuing and pressing need of contributions and bequests —both for general and specific endowment, and of income to be judiciously used. Your response will be most earnestly appreciated.

Checks should be made payable to The Franklin Institute, and sent to The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia 3, Pennsylvania.

Where property is transferred, title should be in the name of The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

We shall be glad to supply any additional information regarding gifts and memorials. Please write to the above address, attention of the Endowment Department.

NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, EXECUTIVE DIRECTOR

STAR OF BETHLEHEM

Christmas in Philadelphia would hardly be complete without the annual Planetarium demonstration of the Star of Bethlehem. The spectacle and the accompanying lecture as it is given this year will not prove to be any disappointment. Like everything else associated with the better ways of celebrating the festival it follows tradition, that is to say, the tradition established by the Planetarium itself in previous years.

It is not generally recognized there is some dispute concerning the actual year of the Nativity arising from errors that crept into thinking before the conception of the heliocentric theory of the Copernicans was accepted. The astrologers founded their convictions upon the theory that the universe was constructed of a series of concentric spheres with the earth at its center. The outer sphere was supposed to exercise some occult influence upon the inner sphere. When the modern heliocentric system was introduced, together with the conception of infinite space where there could be neither inner nor outer spheres, the astrologer was deprived of all basis for his beliefs.

Not all the ancient ideas of astronomy were fallacies. For example, the fundamental idea of time based upon the motions of the earth was not misconceived. The ambitions of certain Roman emperors who sought to perpetuate their names threw the calendar into confusion to such an extent that it has become a difficult matter to disentangle the actual year of the Nativity.

Opportunity is taken during the Christmas Planetarium demonstration to draw attention to a rare conjunction of planets which occurred in the year 7 A.D., and reasons are given for supposing that this may have been the actual year of the Nativity. In presenting the scientific approach to the subject care is taken not to obscure the devotional attitude. While certain celestial phenomena are admitted to have occurred that may have some significance in the ancients' thinking, the Star of Bethlehem remains the focal point of the demonstration.

Each year at this time the Planetarium demonstration is devoted to an examination of the skies at Christmas time, going back as only the Planetarium can to the night when shepherds, wise men, and kings peered at the heavens and found there the symbol of their faith. Appropriate music and an ingenious use of lighting assist the spectator to recapture the mystery and the spirit of the season.

The story of the Star of Bethlehem never fails to renew its interest and those who have witnessed the Planetarium version return year after year to renew their acquaintance with it. To those who see the demonstration for the first time there comes the awed realization that here is a new method for replenishing faith by reviving old traditions and investing them with new vigor. If by any chance members have not seen one of these Christmas demonstrations, they are recommended not to miss the opportunity this year to see the current version. Those who have seen previous demonstrations will only need to be reminded that December is the month when it may be seen.

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

NICOL H. SMITH, DIRECTOR

A NEW TOOL FOR BEARING MATERIAL AND LUBRICANT RESEARCH

BY

GEORGE ROBINSON

The Association of American Railroads, central coordinating and research agency of the railway industry, is carrying on research to find why hot-boxes occur and how to prevent them. AAR gave us a part of this big job, to find how much effect bearing materials have on the

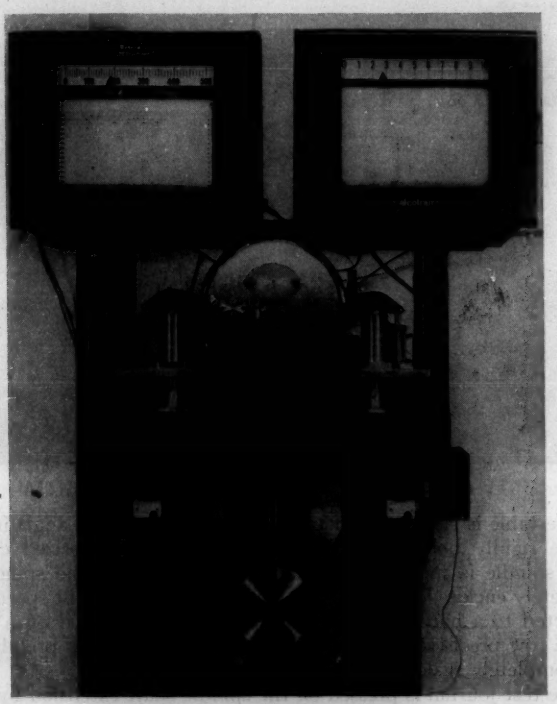

FIG. 1.

overheating of journal bearings, particularly where the lubricant supply might be deficient. We are making an extensive survey of existing and special bearing materials, using an unusual testing machine built by Engineers in the Mechanical Engineering Division. This equipment is so versatile that it may successfully be used to investigate frictional effects under a great many other bearing and lubricant applications.

Basically, the machine consists of a frame, containing the bearing specimen, which is suspended on the cantilevered end of a rotating journal. An over-all picture of the apparatus is shown in Fig. 1, and in Fig. 2 it is shown in actual operation.

FIG. 2.

The table is ruggedly constructed of steel plate and angle iron and can be rigidly bolted to the floor. A precision-motorized constant speed spindle is mounted on the table as shown. The spindle is a completely enclosed compact unit consisting of a constant speed motor connected to a hardened steel spindle which is mounted on a pair of double row precision taper roller bearings. The unit is prelubricated and completely sealed.

The test journal is pressed on the spindle shaft extension by means of a machine screw and plug. When the weight of the frame is placed

on the journal, the surface of the bearing material flows until the area of contact with the journal is large enough to carry the load. When the journal is started, the friction force imposed on the specimen causes the frame to shift until the guide roll on the frame comes in contact with the end plate which is mounted on the motor frame. Once the guide roll has contacted the end plate, a couple is imposed on the frame which is then restricted to rotate about the center of the journal. Even slight rotation of the frame is picked up by suitable instruments and continuously recorded by means of two differential transformers which are supported by brackets mounted on the table.

A thermocouple well is provided in the specimen holder, so that bulk bearing temperature readings can be continuously recorded throughout the entire test. Oil is supplied to the bearing surface during the test for "running in" characteristics of bearing material journal combinations. The roller is partly submerged in the oil and carries it up to the journal which then carries it to the bearing surface. During the test for bearing materials operating under mixed film and boundary lubrication conditions, felt pads on which known amounts of oil are placed are used to supply oil to the bearing surfaces.

After the "running in" characteristics are determined, the oil is removed and the journal and bearings are dried. Then the journal is turned over by hand a few times so that it will be coated with a thin film of lubricant. Thus when the second phase of the test is started, the initial value of friction coefficient will be obtained under true boundary lubrication conditions. As the test progresses, oil is extracted from the pad and is brought up to the bearing area. The oil fills the valleys in the bearing surface as the peaks are being worn down. Conditions then gradually improve. The coefficient of friction gradually reduces and finally reaches a value somewhere between those characteristic of full fluid and boundary lubrication conditions.

After this, the temperature will constantly increase, and the coefficient of friction begins to increase as the effectiveness of the oil is reduced. Contact ratio increases and finally the coefficient of friction reaches the value obtained during the initial part of this test; i.e., the value obtained under true boundary lubrication conditions. Now the behavior of the material operating under conditions of boundary lubrication can be observed.

Preliminary tests with this apparatus indicate that various materials do exhibit marked differences in behavior, not only during run-in to full fluid operation, but also during operation under mixed film and boundary lubrication conditions, and that the machine does give good reproducible results. This latter fact indicates that the apparatus will be helpful in evaluating various lubricants in assisting running in of a bearing and during operation under mixed film and boundary lubrication conditions.

EVALUATING PISTON PUMPS AND MOTORS FOR HIGH PERFORMANCE HYDRAULIC SYSTEMS *

BY

R. H. MARVIN

The demand for increased accuracy and response of hydraulic transmissions for industrial and military applications requires a thorough understanding of the requirements of the components that are to be used. The discussion is limited to a commonly used form of variable speed transmissions, one that is composed of a constant speed, variable displacement machine hydraulically coupled to a fixed displacement machine. The output of the fixed displacement element is thus controlled by the displacement of the constant speed element.

The essential requirements of the fixed and variable displacement elements of this transmission are approached from the standpoint of good dynamic performance and minimum energy dissipation. Parameters are discussed which will serve as figures of merit in the selection of the components which go to make up the transmission. Types of piston pumps and motors are discussed with respect to desired characteristics and optimum parameters.

One of the important factors which is considered in the evaluation of piston pumps and motors for such applications is the dynamic characteristic of the fixed displacement element. Here the interaction of inertia, torque, and velocity are considered in the selection.

Another point of considerable importance is the effort by which the displacement of the variable element is changed. The obvious advantage of only having to supply a low power source for this purpose requires that stroking efforts be small, uniform, and with a minimum of dynamic influence.

Other features of the transmission which are considered are the influence of the volume of fluid in the active system attributed to the components themselves, the no-load or standby losses when no fluid is being displaced, the ability of the fixed displacement element to operate at low speeds with a minimum of velocity fluctuation and general effects of volumetric and mechanical inefficiency.

* Abstract of a paper presented at the National Conference on Industrial Hydraulics, October 14, 1954, in Chicago. The full paper will be published in the *Proceedings* of this conference.

NOTES FROM THE BARTOL RESEARCH FOUNDATION

W. F. G. SWANN, DIRECTOR

THE LATITUDE EFFECT OF COSMIC RADIATION *

M. A. POMERANTZ

During the course of a program of cosmic-ray investigations conducted in India, absolute intensity measurements were obtained at two stations on the ground. The latitude effect at low altitudes is defined by the relationship, $L = 1 - \frac{N(\lambda_2)}{N(\lambda_1)}$, where $N(\lambda_1)$ is the intensity at $\lambda > 40°$ and $N(\lambda_2)$ is the intensity at low latitude λ_2. Near sea level the latitude effect with respect to 18° N. in India is $L = 8.8 \pm 0.6$ per cent, and at an altitude corresponding to 567 mm. of Hg, at 23° N., it is 13.1 ± 0.6 per cent. The latitude effect does not vary rapidly with interposed absorber thickness. Vertical G-M counter trains yield approximately the same latitude effect as ionization chambers throughout most of the atmosphere.

* Assisted by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

HALL EFFECT IN METALLIC THORIUM *

J. H. BODINE

Complete understanding of thorium oxide electrolysis requires knowledge of the electronic processes both in thorium oxide and in metallic thorium. Hall data for neither of these substances exist in the literature at present and work is in progress at Bartol to determine these quantities. Results for thorium metal have been obtained; the material shows normal Hall effect, signifying conduction by negative carriers rather than holes. The value of the Hall coefficient is in line with that for common metals. Two specimens yield values 12.5×10^{-12} and 10.5×10^{-12} volts-cm-amp^{-1}-gauss^{-1}, respectively.

* Assisted by the U. S. Office of Ordnance Research.

SHORT TIME POLARIZATION STUDIES IN THORIUM OXIDE CRYSTALS *

W. E. DANFORTH

As reported formerly, passage of small currents through thoria crystals results in rapid growth of polarization potential, the polarization decaying when the applied current is interrupted. A wide range of time-scale is involved in this phenomenon: hours are required before equilibrium is reached, yet the initial effects are so rapid that oscillograph observations are required to determine the initial rise. Such

observations have been made over temperatures between 900° and 1300° C. The initial conductance is found to obey Ohm's law; its temperature dependence is of the usual exponential form with an activation energy of 1.1 volt. Optical absorption measurements show an absorption maximum at 4000 A.U. Assuming a simple semi-conductor model this is tentatively ascribed to a donor band at 3.1 volts below the conduction band. The above activation energy yields a value of 2.2 volts which, in view of the Franck-Condon principle, may correspond to the same donor band.

* Assisted by the U. S. Navy Bureau of Ships and by the U. S. Office of Ordnance Research.

THE LEVEL SCHEME OF In^{115} *

J. VARMA ** AND C. E. MANDEVILLE

The disintegration of the 2.3-day Cd^{115} and its isomer, the 43-day Cd^{115}, has been studied with thallium-activated sodium iodide counters, anthracene counters, and coincidence methods. The levels of In^{115} have been shown to have excitation energies of 0.335 ($T_{\frac{1}{2}}$ = 4.5 hr.), 0.595, 0.825, 0.858, 0.935, 1.30, and 1.42 Mev., the first four levels being excited in the decay of the 2.3-day period alone and the latter three in decay of the 43-day activity only. The gamma transitions from the 1.3-Mev. level proceed directly to the ground state of In^{115} while all the transitions from the 1.42-Mev. level terminate at the 0.935-Mev. level. The gamma transitions from the 0.595, 0.825, and 0.858-Mev. levels lead to the metastable state at 0.335 Mev. About three per cent of the transitions from the 0.858-Mev. level terminate at the 0.825-Mev. level which in turn de-excites by way of a 0.230 Mev.–0.260 Mev. gamma ray cascade or by emission of a 0.490-Mev. quantum in the cross-over transition. The angular correlation function for the 0.485-Mev.–0.935 Mev.-cascade in the decay of the 43-day Cd^{115} is found to be essentially isotropic. A level scheme for In^{115} has been established by these measurements.

* Assisted by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

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RADIATIONS FROM Y^{90}, Zr^{97}, Pr^{142}, AND Pr^{143} *

B. L. SARAF **, J. VARMA *** AND C. E. MANDEVILLE

The radiations of the above listed radionuclides have been investigated with the aid of scintillation spectrometers employing crystals of NaI(T1). A pure sample of Y^{90}, obtained from Oak Ridge, was found to emit gamma rays in an amount of at most 10^{-6} photon per disintegration. Zr^{97} was produced at Brookhaven by slow neutrons on isotopic Zr^{96}. The gamma rays of the 17-hr. $Zr^{97} \xrightarrow{\beta} Nb^{97} \xrightarrow{\beta} Mo^{97}$ are of energies 0.67, 0.75, and 1.6 Mev., the hardest quantum[1] appearing in only two per cent of the disintegrations. A sample of praseodymium

oxide (99.98 per cent pure) was irradiated by neutrons to produce Pr^{142} which was found to decay with emission of a single gamma ray at 1.6 Mev. No gamma rays were detected in the disintegration of Pr^{143}. Any present were estimated to have an intensity of upper limit 10^{-5} photon per disintegration.

* Assisted by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

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*** Research Fellow, Bartol; at present at the University of Glasgow, Scotland.

[1] Previously reported at 1.42 Mev. by Mandeville, Shapiro, Mendenhall, Zucker, and Conklin, JOUR. FRANKLIN INST., **254**, 381 (1952).

ENERGY LEVELS OF Rh^{103} FROM THE DECAY OF Pd^{103} AND Ru^{103} *

BABULAL SARAF **

The decay schemes of Pd^{103} and Ru^{103} have been studied with the use of two scintillation spectrometers in coincidence. It has been observed that the electron capture activity of Pd^{103} is accompanied by faint gamma radiation having the several quantum energies of 40, 65, 300, 365, and 495 kev with absolute intensities per disintegration of 1×10^{-3}, 4×10^{-5}, 1.2×10^{-4}, 6.6×10^{-4}, and 1×10^{-4}. The gamma rays of energy 65 and 300 kev were found to be in coincidence. The inner bremsstrahlung spectrum associated with the capture transition leading to the 57-minute isomeric level in Rh^{103} is of intensity small in comparison with that of the above mentioned gamma rays. The β-decay of Ru^{103} is accompanied by gamma rays of energies 55, 440, 495, 555, and 610 kev with absolute intensities per disintegration of 1×10^{-2}, 5×10^{-3}, 0.90, 5×10^{-3}, and 6×10^{-2}. A β-spectrum of end point 110 ± 10 kev is coincident with the 610-kev gamma ray. A level scheme for Rh^{103} with probable orbitals has been proposed.

* Assisted by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

** Research Fellow, Bartol; on leave of absence from Agra College, India.

THE LOGARITHMIC DERIVATIVE OF THE ψ FUNCTION*

W. F. G. SWANN

The logarithmic derivative of the ψ function plays an important part in quantum mechanics, in that its assignment over the boundary determines uniquely the solution of the differential equation for ψ within the boundary, except for an arbitrary constant. While the truth of this statement is recognized, its formal proof seems rather difficult to find in most presentations in which the result itself is used. For these reasons, the following considerations may be of interest to those who are concerned in this matter.

The fundamental equation in which we are interested is

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0 \tag{1}$$

where V is a function only of r.

Throwing this into polar coordinates, we seek solutions of the form

$$\psi = R\,\Theta\,\Phi \tag{2}$$

where R, Θ, Φ are functions only of r, θ, and φ, respectively. The equation of R is then

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right) + \left(k^2 - \frac{8\pi^2 m}{h^2}V(r) - \frac{l(l+1)}{r^2}\right)R = 0 \tag{3}$$

where l is an integer, and $k = 2\pi mv/h$.

Suppose that for a given k, l, and $V(r)$ there are two solutions R_1 and R_2. Then, since R_1 and R_2 both satisfy (3),

$$\frac{1}{R_1}\frac{d}{dr}\left(r^2\frac{dR_1}{dr}\right) - \frac{1}{R_2}\frac{d}{dr}\left(r^2\frac{dR_2}{dr}\right) = 0,$$

$$R_2\frac{d}{dr}\left(r^2\frac{dR_1}{dr}\right) - R_1\frac{d}{dr}\left(r^2\frac{dR_2}{dr}\right) = 0.$$

Let us integrate this equation along a radius vector at fixed values of θ and φ from $r = r_0$ to an arbitrary value $r = r$. The result is

$$r^2\left[R_2\frac{dR_1}{dr} - R_1\frac{dR_2}{dr}\right] - r_0^2\left[R_{20}\left(\frac{dR_1}{dr}\right)_0 - R_{10}\left(\frac{dR_2}{dr}\right)_0\right]$$
$$= \int_0^r r^2\left(\frac{dR_2}{dr}\frac{dR_1}{dr} - \frac{dR_1}{dr}\frac{dR_2}{dr}\right)dr$$

when the subscript zero refers to $r = r_0$. The right hand side of this equation is zero. Hence

* Assisted by the Joint Program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

$$r^2\left[R_2\frac{dR_1}{dr} - R_1\frac{dR_2}{dr}\right] = r_0^2\left[R_{20}\left(\frac{dR_1}{dr}\right)_0 - R_{10}\left(\frac{dR_2}{dr}\right)_0\right]. \quad (4)$$

Suppose now that the logarithmic derivative is assigned at $r = r_0$. Then

$$\frac{1}{R_{10}}\left(\frac{dR_1}{dr}\right)_0 = \frac{1}{R_{20}}\left(\frac{dR_2}{dr}\right)_0,$$

$$R_{20}\left(\frac{dR_1}{dr}\right)_0 = R_{10}\left(\frac{dR_2}{dr}\right)_0.$$

Hence the right hand side of (4) is zero, and

$$R_2\frac{dR_1}{dr} - R_1\frac{dR_2}{dr} = 0,$$

$$\frac{1}{R_1}\frac{dR_1}{dr} - \frac{1}{R_2}\frac{dR_2}{dr} = 0,$$

$$\frac{d}{dr}\left(\log\frac{R_1}{R_2}\right) = 0,$$

$$\log\frac{R_1}{R_2} = \text{const.}$$

$$\frac{R_1}{R_2} = \text{const.}$$

Thus, R_1 and R_2 are the same except for a constant. The conclusion is that the assignment of the logarithmic derivative at $r = r_0$ determines R for all values of r, except for a constant; and this result, of course, holds for all values of θ and φ. Thus the assignment of the logarithmic derivative over the sphere determines ψ at all points except for a constant.

Note. It is of interest to inquire what would happen had we not restricted ourselves to solutions of the form (2).

Our two supposed solutions ψ_1 and ψ_2 would both satisfy (1), so that

$$\frac{1}{\psi_1}\nabla^2\psi_1 - \frac{1}{\psi_2}\nabla^2\psi_2 = 0,$$

$$\psi_2\nabla^2\psi_1 - \psi_1\nabla^2\psi_2 = 0. \quad (5)$$

Applying Green's theorem throughout a volume bounded by two surfaces,

$$\iiint(\psi_2\nabla^2\psi_1 - \psi_1\nabla^2\psi_2)d\tau = \iint\left(\psi_2\frac{\partial\psi_1}{\partial n} - \psi_1\frac{\partial\psi_2}{\partial n}\right)dS,$$

the surface integral being taken over the two surfaces. Thus, in view of (5)

$$\iint \left(\psi_2 \frac{\partial \psi_1}{\partial n} - \psi_1 \frac{\partial \psi_2}{\partial n} \right) dS = 0,$$

$$\iint \psi_2 \psi_1 \left[\frac{\partial}{\partial n} \log \psi_1 - \frac{\partial}{\partial n} \log \psi_2 \right] dS = 0. \tag{6}$$

If the logarithmic derivative is assigned over one of the two surfaces, say S_0, then the integral in (6) is zero for that surface. If the other surface S is an arbitrary surface, we have for this surface

$$\int\int_S \psi_2 \psi_1 \frac{\partial}{\partial n} \log \left(\frac{\psi_1}{\psi_2} \right) dS = 0.$$

This does not enable us to conclude that $\frac{\partial}{\partial n} \log \left(\frac{\psi_1}{\psi_2} \right)$ is zero at each point.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, DIRECTOR

GROWTH-PROMOTING PROPERTIES OF ELECTROPHORETIC FRACTIONS OF CHICKEN EMBRYO EXTRACT

BY

J. O. ELY

Embryo extract has been recognized for a long time as an excellent source of the growth substances necessary for the culture of mammalian cells *in vitro*. Many attempts have been made to separate the growth factors but no clear-cut separation has been accomplished.

Various fractions of chicken embryo extract were made by Hueper *et al* (1) by chemical means, no one of which contained the growth factors to the exclusion of the others. By differential centrifugation and precipitation with streptomycin, Kutsky (2) obtained a non-dialyzable fraction from chicken embryo extract which possessed most of the growth-promoting activity.

Chicken embryo extract has been fractionated in the Tiselius electrophoresis apparatus and the several fractions compared in their growth-promoting powers.

METHODS

Freshly prepared undiluted chicken embryo (8 day) extract was centrifuged at 140,000 G (45,000 r.p.m.) for 30 min. The supernate (14 ml.) was then dialyzed against 1200 ml. of Tyrode solution in a refrigerator for 18 hr. The dialyzed extract was separated in a Tiselius electrophoresis apparatus in Tyrode solution at pH 7.4 into the following 5 fractions:

1. Upper Positive (UP)
2. Upper Negative (UN)
3. Lower Positive (LP)
4. Lower Negative (LN)
5. Bottom Fraction (BF)

ASSAY OF THE FRACTIONS

Explants of second transfer cultures of 8-day chicken embryo heart cells were used.

The basal control medium was composed of 1 part Tyrode solution, 1 part distilled water and 2 parts chicken plasma. The other media were made by substitution of the unfractionated supernate, or of an electrophoretic fraction, for the distilled water in the basal control medium.

The cultures were incubated at 39° C. for 2 to 3 days and photographed. The areas of growth were determined comparatively by weighing paper cutouts of enlarged images of the cultures after removal of the images of the original explants and after subtractions of the weight values representing the growth on the basal control medium.

RESULTS

The results are represented in Fig. 1 in comparative form and not in absolute units.

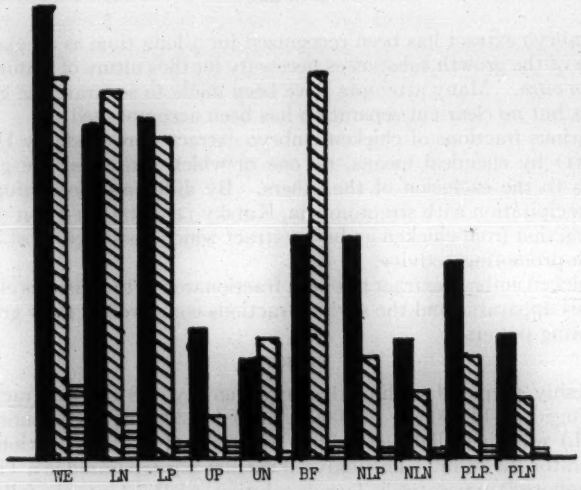

FIG. 1. Comparative growth-promoting powers of electrophoretic fractions of chicken embryo extract.

WE	Whole Extract	BF	Bottom Fraction
LN	Lower Negative	NLP	Negative of Lower Positive
LP	Lower Positive	NLN	Negative of Lower Negative
UP	Upper Positive	PLP	Positive of Lower Positive
UN	Upper Negative	PLN	Positive of Lower Negative

■ Growth
▨ Nitrogen
▤ Phosphorus

It may be seen that all fractions promoted growth. The lower positive and the lower negative were the most active fractions and compared favorably with the unfractionated extract. The upper positive and the upper negative fractions were the poorest.

There appeared to be a positive correlation between the growth-promoting powers of the fractions and their content of nitrogen and phosphorus (Fig. 1). If nitrogen and phosphorus, or phosphorus alone,

were low, growth was restricted. If an ample supply of nitrogen and phosphorus compounds was present, good growth response was obtained.

Electrophoretically there were 3 chief components, one of rapid mobility, one of slow mobility and one of intermediate mobility. Since the lower negative and the lower positive fractions were high in growth-promoting properties, these properties appeared to be more closely associated with the component of intermediate mobility than with the faster or slower moving components. The contents of the negative arm and the positive arm were therefore each refractionated into a positive and a negative fraction in an effort to isolate the more active intermediate component. The results showed, however, that in each of these experiments the positive and negative fractions were equal in growth-promoting properties, which again appeared to be controlled by the content of nitrogen and phosphorus compounds.

It may be concluded that all of the electrophoretic fractions of embryo extract contained growth-promoting substances which apparently were associated with the nitrogen and phosphorus compounds.

REFERENCES

(1) W. C. HUEPER, A. ALLEN, M. RUSSELL, G. WOODWARD, AND M. PLATT, *Amer. J. Cancer*, 17, 74 (1933).
(2) J. KUTSKY, U. S. ATOMIC ENERGY COMM. UCRL-2270 (July 1953).

MILLIMICROSECOND PULSE TECHNIQUES, by Ian A. D. Lewis and Frank H. Wells. 310 pages, diagrams, 15 × 22 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $7.50.

This book is one of a series which is aimed at reporting recent progress in electronics and applied physics. As such, the scope and arrangement are reminiscent of the various books in the Radiation Laboratory Series of 1948 and 1949. The latter series was written for the practicing engineer, each volume being the result of experience in the Radiation Laboratory at M.I.T. during the war-time radar development. These M.I.T. handbooks have proved to be one of the most useful weapons in the engineer's arsenal.

The present book also brings together in one place such information formerly scattered or unavailable. As in the Radiation Laboratory Series, the material is selected according to its end use. In the present case, the material is pertinent for the engineer who is working in a fast time scale, 10⁻⁶ to 10⁻⁹ second.

In selecting best material, the bulk of it falls naturally into five subjects which make up one chapter each. The first subject is transmission lines. In the usage of the present treatise in this book, every piece of wire is a transmission line if one end is another, goal, and is millimeter. The theoretical material on transmission lines is limited to those in engineering discussion of what can be done with lines is undertaken. The second subject, transformers, develops usually set of the best for these short times and high frequencies. Transformers sometimes due to small set, considered configurations. Some of these are described in depth.

Chapter five covers various schemes for the generation of short pulses, and also some material on the subject of shaping such a pulse, once generated. These additions include some material on attenuators, and on a vacuum-tube voltmeter for reading the peak amplitude of pulses 10⁻⁸ sec. long or more. These additions seem to be included here because they would not fit into the earlier chapters.

The last two of these five chapters are on amplifiers, for handling the pulses generated in chapter four, and on cathode ray oscilloscopes. This last chapter is the longest of the five, and deserves to be since finding out what one had time is perhaps the hardest part of working in this time scale.

These central five chapters are bracketed at the one end by a quick review of circuit theory, and at the end of the book by two chapters on engineering applications. As would be expected from the authors whose work is at Harwell, nearly all the applications are to nuclear physics.

Worth is the millimicrosecond has range a recent enough so that in these convenient single source of information exists as far as this reviewer is aware. Lewis and Wells have produced a book which is full of useful design data in his subject. They deserve the thanks of every engineer who is struggling with a problem requiring the use of millimicrosecond pulse techniques.

James Bates

A History of Mathematical Notations, by Albert Eagle. Liber Second edition. 452 pages, diagrams, 15 × 22 cm. Cambridge, Harvard University Press, 1952. Price, $9.00.

For the past twenty-five years Professor Cajori's book has been the standard work on the history of mathematical notation. This new edition is more than a reprint. Not only have there been many additions to the text in a substantial addition of valuable new material has given the work a broader appeal. The four introductory chapters are responsible for the introduction of many present day mathematical symbols.

Although technology does not exhaust the end of the development of the human mind,

it forms a characteristic and convenient segment for investigation because the process of innovation in mechanical apparatus can be traced more accurately than in religious, ethical, and philosophic concepts. However, the process of development has greater significance than the production and control of power and the evolution of operative mechanisms. The broader field has not been adequately explored, although the effect of geographic environment has received considerable attention. In his chapter on Technology in Economic History, the author lays emphasis upon the fact that human societies not only select an environment, they proceed to make their environment by transforming it.

The role of economic forces in the development of technology is of primary importance but, the author demonstrates, while the direction of advance is normally through the improvement of the productive processes in current use, the sequence may be broken through changes inspired by concepts derived from philosophy or science by men who are in advance of their times. There is, in fact, no one system of events that leads to technological advancement, but many. The ideas developed by Professor Usher in these new introductory chapters furnish a key to the principles of analysis that are employed in the descriptive chapters that form the main body of the book.

After dealing adequately with the early history of the mechanical sciences in antiquity, the book treats of the development of power sources through water wheels, windmills, steam engines, down to the recent gas turbine. The chapter on the history of textile machinery has some new material on the techniques practiced in Syria and China at the beginnings of the Christian era. The history of clocks and watches has been improved with some revisions and additions. Those chapters on Leonardo da Vinci and on the origin of printing remain substantially unchanged. The bibliographies have been brought up to date.

An interesting note has been struck in the printing of the volume. It is the first complete book we have seen produced by the new photographic typesetting process which employs no metal type. In adopting the process the publishers made a bold experiment, but the results are gratifying, for both the text and the illustrations (which are numerous) are very clear, and make a handsome volume.

Altogether this is an important and necessary addition to the technical bookshelf, and in its new format should make an appeal to the social economist and historian as well as to the technician. We know of no other book on the subject that it so scholarly and yet so readable. T. C.

VEGETABLE FATS AND OILS, by E. W. Eckey with Lawrence P. Miller. ACS Monograph No. 123. 836 pages, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1954. Price, $16.50.

This very informative volume describes in detail all of the important vegetable oils and fat used in industry. The botanical origin, physical and chemical properties, and test methods are presented logically, and in readable fashion. The botanical origin and general description of the numerous oils and fats which occupy most of this book are preceded by several introductory chapters in which the history and detailed chemical and physical properties of the subject are listed.

The various manufacturing methods, and the numerous uses of fats and oils are given, but emphasis is placed properly on the presentation of the chemistry and physical properties of these materials. The important properties of the various fatty acids, saturated and unsaturated, are listed with their natural occurrence in vegetable fats. The importance, distribution in the oils, and the chemistry of the less known components are described. These include the phospholipides, sterols, tocopherols (Vitamin E) and several others.

The physical properties of the oils and fats, and their measurement, constitute a profitable chapter for chemists interested in the subject. The importance of these tests in determining the identity and purity of the materials is emphasized. The measurement of refractive index, absorption spectra, viscosity, solubility, and surface properties are gone into in some detail. Tables and plots included in this discussion make this chapter

a valuable source of information. Other physical properties of importance such as vapor pressure, density, specific heats, and heats of vaporization are discussed and also presented in tabular form.

The description of the chemical properties and reactions of fats and oils is factual and comprehensive and includes details of the more important reactions of concern in industry such as hydrolysis, hydrogenation, and reactions related to the degree of unsaturation.

The references are copious and should be of real value to workers in the field.

S. MUCHNICK

TRANSIENT ANALYSIS OF ALTERNATING-CURRENT MACHINERY, by Waldo V. Lyon. 310 pages, diagrams, 15 × 24 cm. Cambridge, The Technology Press; New York, John Wiley & Sons, Inc.; 1954. Price, $7.00.

In 1918 C. L. Fortescue published a paper in the A.I.E.E. Transactions entitled "Method of Symmetrical Co-ordinates Applied to the Solution of Polyphase Networks." From that period down to the present the method of symmetrical components in the analysis of A-C machinery has been vigorously taught at the Massachusetts Institute of Technology. The author of the present book, "Transient Analysis of Alternating-Current Machinery," has been an active member of the staff for an even longer period (1905) and has become widely known for his writings in the electrical machinery literature. No more authoritative writer in this field could be desired than M.I.T.'s Professor Waldo V. Lyon.

This new book is remarkable in that no part of it is merely descriptive of A-C machinery construction. The entire volume is devoted to a powerful, mathematical analysis placing before the reader essentially new material in this field. The specific task which Professor Lyon has undertaken is that of applying the method of symmetrical components for the analysis of other than steady-state performance. The solution of Kirchhoff differential equations provides the form of analysis employed to solve the transient condition whence the symmetrical components replace the actual potentials and currents.

In order to achieve a solution to the Kirchhoff differential equations it is actually necessary to supply constants of a nearly equivalent "ideal" machine. The critical issue here is of course the experience and judgment that can be mastered by the individual engineer in the use of design and measured data to determine the characteristics of the "ideal." Professor Lyon recognizes this point and extends his helping hand of long experience to guide the reader toward a true mathematical analysis.

However, the author emphasizes a complete understanding of what is taking place by means of these mathematical sketches. It is assumed that once this condition of understanding has been reached, nothing further need be said. There is little by way of suggestion of what to do to change the situation, and one may presume correction is thought to be obvious.

What type of problem is this book actually intended to solve? Typical is the matter of rotor oscillation about a mean position of slip during operation. Another example: What happens to the current if the breakers open, disconnecting an induction motor from the line, and then close at a later time when the speed has fallen? What differences accompany the rotor oscillation in machines having a uniform air gap and those having salient poles? There are 25 selected problems in the back of the book, and several solutions carried out on a differential analyzer at M.I.T.'s Center of Analysis are also presented.

One might wonder at the prospects for sale of such a specialized reference book. This is an unfair question to raise, however, for any thoroughly technical contribution is subject to such wonderings, and our progress would certainly be checked if we heeded them. One can therefore praise the publisher for making available advanced works of this type, since the academic and technical contribution in this case is unquestionable.

C. W. HARGENS

THE TECHNICAL REPORT, edited by B. H. Weil. 485 pages, diagrams, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1954. Price, $12.00.

In the opinion of this reviewer, *The Technical Report* ranks with Hayakawa's "Lan-

guage in Action" and Fowler's "Modern English Usage" as a top-of-the-shelf item. For in less than 500 pages, Editor Weil has compiled a very serviceable handbook for nearly everyone in whose occupation technical reports play a part. He has essayed complete coverage of his topic; since he chose so well from the great mass of writings on the topic, he has very nearly succeeded.

A chapter each is given to ten papers from a report symposium sponsored in 1953 by the American Chemical Society. Fourteen other chapters that elaborate upon or complement the basic ten were contributed specifically for the book. Each chapter falls under one of five major headings: functions of technical reports, preparing and processing, distributing, filing and using.

Part One, comprising a chapter on the purposes of government reports and another on industrial reports is gratifyingly brief and to-the-point. The all-too-infrequent combination of economy of words with thoroughness of treatment is the outstanding feature of chapters 3 to 11, comprising the second part, and including: guides to writing and illustrating progress and technical reports, literature summaries and oral reports; the usual common writing faults; editing procedure; and knowledgable comparisons of duplicating and binding operations. Report writers, and editors of course, will find these topics interesting and well executed.

Parts Three and Four—distributing and filing—are of less interest to report writers and readers, perhaps, than to managers, librarians and editors. These chapters (12 through 21) are well organized and offer detailed advice concerning indexing, cataloging, storage and abstracting.

Using technical reports, the final part of the book, affords an excellent chapter on making report files useful, and a nearly complete review of (current) sources that disseminate government-controlled reports.

Most chapters carry generous reference listing, but the reader will not feel compelled, by lack of detail in the text, to seek many out. We can only conclude that Mr. Weil has done a service in bringing these excellent papers together, and recommend the whole as a workman-like report on the practical problems of communicating technical information.

E. H. NELSON

INTRODUCTION TO ATOMIC PHYSICS, by Otto Oldenberg. Second edition, 421 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $6.00.

This revision of an excellent textbook is more than a corrected reprinting of the first edition. The author is to be congratulated on having taken the more difficult course of recasting some chapters, in order to incorporate new material and to improve the presentation of the old. In general, however, the same order of presentation has been followed; and the same care has been taken to distinguish between observed facts and theoretical explanations.

The new material has increased the length of the book by more than ten per cent, in spite of some deletions of background information. Also, additional text has been shifted into smaller type to distinguish between elementary and more advanced concepts. An important addition has been in the number of problems. Some of them now require calculus, although the text itself is written without recourse to calculus. There are also a few new illustrations, for example, a diagram showing the geometry of an x-ray grating and one showing the effect of the ionosphere on radio propagation.

The revision is up to the minute and very thorough. Thus the periodic table of the elements now includes Nos. 97 and 98; the 1953 values for physical constants have been incorporated; and the text describes such recent devices as the photomultiplier tube, transistor, and the field electron microscope. The growing importance of study of the solid state has been recognized by segregating in one chapter the previously scattered sections dealing with this subject, and adding considerable new material to them.

In addition to the intended use of this book as a college text for students who have studied elementary chemistry and physics, it is also recommended to engineers and other non-physicists as a reference book for concise descriptions of phenomena and instruments in the field of atomic physics.

JOHN S. BURLEW

MATHEMATICAL STRUCTURE OF THE THEORIES OF VISCOELASTICITY, by Bernhard Gross. 74 pages, diagrams, 16 × 25 cm. Paris, Hermann & Cie., 1953. No price.

This is a monograph to describe the foundation and structure of the mathematical framework common to all theories of viscoelasticity, especially the connections between superposition principles, and distribution functions of relaxations times with the main emphasis on mathematically rigorous treatment.

The different approaches described in existing literature have been correlated to know exactly where common treatment is possible. The properties in terms of distribution functions are discussed with all the pertinent mathematical relationships. This has been discussed not only for cases having continuous distribution, but also for "line spectra" models. A table of distribution functions proposed in literature is included.

This book is an important summary of the fairly involved mathematical theory used in modern discussions of mathematical elasticity. Most of the mathematical treatments are known from other publications but the author has given himself great pains in giving the treatment the highest possible level. From the practical standpoint, this treatment has two drawbacks: (1) The fitting of the theory to experimental results has not been tried, and (2) The limiting of the treatment to linear viscoelasticity eliminates a lot of possible practical applications.

The author has been active in the field for a good number of years and his treatment is, in this publication, entirely up to his accepted reputation. WLADIMIR PHILIPPOFF

MATERIALS OF CONSTRUCTION, by M. O. Withey and G. W. Washa. Eighth edition, 870 pages, diagrams, illustrations, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1954. Price, $9.00.

When this book first appeared more than 50 years ago, it was prepared for the purpose of assembling all sorts of scattered data on materials of construction under one cover. Prior to that time, one had to search periodicals, papers and books to find such data. Since the book was first published, it has undergone many changes, this present edition being the eighth. Many improvements over the last one appear. In the current edition, there is for the first time information on new testing equipment, on non-destructive testing, on new types of cement and concrete aggregates; and there are many new data on iron and steel.

Intended to be used as a textbook as well as for reference, the book begins with a review of the principles of the mechanics of materials. This leads naturally into the subject of testing of structural materials and apparatus for mechanical tests. There are then sections on timber, building stone, clay products, portland cement, mortar and concrete. Under iron and steel, information is given on metals and their ores, manufacture of iron and steel shapes, formation and structure of alloys, alloy steel, cast and malleable iron. The non-ferrous metals and alloys are also discussed. The book is concluded with descriptions of the effect of temperature on the properties of metals and of the fatigue of structural materials.

As a source of ready and up-to-date information on materials of construction, this book will not easily be surpassed. Not only does it contain these data, but each section contains many references for more advanced information on the particular subject. It should prove a valuable reference book for civil and mechanical engineers.

E. W. HAMMER

LINEAR TRANSIENT ANALYSIS, VOLUME I, LUMP-PARAMETER TWO-TERMINAL NETWORKS, by Ernst Weber. 348 pages, diagrams, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1954. Price, $7.50.

This new text by Prof. Weber has been based on material used by him in graduate courses for many years. The benefits of this teaching experience show throughout the book, in its careful, coherent organization, in its attention to fundamental physical concepts, and in its emphasis in all chapters on a complete understanding of the applications of the analytic methods. The book is not an exercise in mathematics, but rather is a closely-knit exposition of the techniques of using well developed mathematical tools in the solutions of problems. It never bogs down in a welter of detail to attain niceties of rigor, but its demonstrations are clear and

compelling, with a strong physical appeal.

These characteristics are demonstrated at the outset in the first chapter, on the concepts of electric circuits and networks. The lumped circuit is a concept, a useful abstraction from reality, an approximation, the shortcomings of which must receive proper consideration at all times. Field theory is the true foundation, and the primary physics law is the conservation of energy, expressed as an energy balance or power balance. The point of view expressed here is so vital that it should really be taught to sophomore students, not reserved for graduates. The chapter continues with a brief discussion of mesh equations, introduces magnetic linkages, and concludes with the nodal analysis.

Chapter 2 gives the classical integro-differential equation analysis of the circuit equations. This has strong physical appeal to the student, since it is a direct attack on the circuit equations, and requires no very novel concepts. But the author does depart somewhat from the usual treatments in that he introduces a careful discussion of discontinuous source functions and their implications with respect to "initial conditions." Analytic approximations to these functions are also given here. The idea of the indicial admittance, and its relation to the complex impedance closes the chapter.

The third chapter, "Analogues," is in some respects a digression, but serves to introduce the concept of a circuit dual. Its section on Lagrange's Equations is so brief as to be unsatisfactory, and is purely formalistic.

The remaining three chapters are given over to the three operational methods, which require a student to show some elasticity in his thinking, to expand his horizons to include more novel concepts. These methods are, of course, the Heaviside operational calculus, the Laplace Transform, and the Fourier method.

The treatment of the Heaviside method follows the Jeffreys formulation, with emphasis on the integral operator. It carries through the shifting theorem and the expansion theorems. The Laplace method is introduced with the direct real transform. Complex functions are introduced only with the inverse transform. A brief discussion of Fourier fundamentals introduces the idea of spectra, and leads to Fourier integrals and transforms. Throughout these three chapters extensive use is made of the same circuits as examples, to provide an excellent correlation of the techniques.

Tables of transforms and other relations are given, and the main text is supported by five appendices on notation, electromagnetic field fundamentals, polynomial roots, matrices and determinants, and functions of a complex variable. An extensive bibliography is the final feature. The engineer who desires to use this book for self study should read these appendices concurrently with the appropriate parts of the text, rather than leaving them till last or for casual reference. Appendix 2 might well be studied before Chapter I is begun.

ALAN C. BYERS

ADVANCES IN CANCER RESEARCH, VOLUME II, edited by J. P. Greenstein and Alexander Haddow. 530 pages, illustrations, 16 × 24 cm. New York, Academic Press, Inc., 1954. Price, $11.00.

Some time ago, the first volume of the above titled book was reviewed by this writer in this JOURNAL. Many of the comments made at that time could well be applied to the second volume. Again it is apparent that each of the various sections is written by a scientist well acquainted with his respective field of interest. The volume diversity and the manner of presentation of the research reported are quite impressive, somewhat more so than the progress toward an understanding of the fundamental nature of the phenomenon in question.

Of the seven sections presented, a large fraction is concerned with carcinogenesis or the conditions which bring about cancer. Most of the others describe studies of the properties of, and the effects of foreign agents upon, cancerous growths. Very little is presented concerning the basic physicochemical processes which characterize normal and abnormal cell growth or mitotic phenomena. Sections on carcinogenesis present discussions of the reactions of carcinogens with large molecules and the effect of the chemical structure of the carcinogen. The latter includes an interesting presenta-

tion of the effectiveness of phenanthrene type of bonds in producing tumors. A general survey and comparison of all types of carcinogenesis is made in another section. Also of great interest in this respect is a critical discussion in favor of the virus theory of cancer initiation. The views presented in the latter section are quite interesting and certainly merit further study.

The remaining sections cover a variety of important aspects of this research, of which three might be classified as techniques of cancer research. These deal with the use of ionizing radiations, low temperatures and the nitrogen mustards.

Other sections present discussions of metabolic effects of cancer, genetic studies and cancer chemotherapy. The section in which the latter is discussed, realistically points out that "although the first human cancer chemotherapy cure remains to be found, numerous studies have advanced considerably the status of cancer thermotherapy in the light of the situation ten or even half a dozen years ago." It is hopeful to note that the author indicates that "developments have revealed agents effective against cancer in animals—some of which are of limited use in man."

The second volume is as extensively referenced as the first, and certainly as valuable a documentation of cancer research.

ALBERT L. MYERSON

THE STEEL SKELETON. VOLUME ONE: ELASTIC BEHAVIOUR & DESIGN, by J. F. Baker. 206 pages, diagrams, 19 × 27 cm. New York, Cambridge University Press, 1954. Price, $8.50.

Despite its rather gruesome title, this book is a worthwhile contribution to civil engineering literature. For years building codes throughout England and in fact throughout the world, have been based largely upon tradition rather than careful rational procedure. Many engineers, particularly in the steel industry, believed that full advantage was not being taken of the excellent qualities of steel in building construction. The Steel Structures Research Committee, therefore, was established by the British steel industry and the Department of Scientific and Industrial Research to thoroughly investigate the application of modern structural theory to the design of all forms of steel structures. This book summarizes results of their investigation.

The Steel Structures Research Committee set out to develop a rational method of designing steel structures. Its first step was to review existing building codes and to show where irrationality was present. Following this, it conducted full-scale tests on three types of buildings—hotel, office building and residential flat. By careful strain measurements it was able to demonstrate that the steel frame structure as exemplified by those three buildings is, surprisingly, for all practical purposes, rigidly framed. That is, the connection of beam to column is essentially rigid. The usual assumption of simple support in designing the beams, while safe, results in a beam that is heavier than necessary. The usual assumption of axial load only in the columns thus results in members that were weaker than designed because the transmitted end moment from the beams was neglected. The Committee then proceeded to develop a rational design method for beams and structures based upon the results of their tests. Unfortunately, while the Committee had recognized the need for simplicity in any design methods in order for them to be practical, their methods were not simple enough. Consequently, their recommendations in 1937 were received with something less than enthusiasm by both industry and consulting engineers and were neglected. Subsequently, greater attempts at simplification of design methods have been made. But, except for a reduction in certain moment coefficients in the old code so that the beams are now lighter in weight, no real notice has been taken of the Research Committee's work.

The review of the old codes showing their irrationality, the procedures and test results of the three types of buildings, the comparison of the test results with results of calculations based upon the codes, the development of new design methods for beams and columns (or stanchions as the British call columns), and the reception of the Committee recommendations are all thoroughly discussed in *The Steel Skeleton*. For one engaged in structural research or in the de-

sign of steel frame structures, this book should be of more than routine interest.

E. W. HAMMER

HANDBOOK OF ELLIPTIC INTEGRALS FOR ENGINEERS AND PHYSICISTS, by Paul F. Byrd and Morris D. Friedman. 355 pages, 16 × 24 cm. Berlin, Springer-Verlag, 1954. Price: DM 36 (half linen); DM 39.60 (linen).

This latest volume of the renowned "Grundlehren" series should be welcomed by every "applied" mathematician. Its authors, both Aeronautical Research Scientists with the NACA with an extensive mathematical background, have admirably succeeded in compiling in the space of 350 pages all detailed information relating to elliptic functions and elliptic integrals which may be required in the solution of most practical problems.

The authors adopt the Legendre-Jacobi definitions and notation as best suited in the majority of practical applications. The general plan of the handbook is as follows: The first 40 pages are devoted to definitions and fundamental relations of elliptic integrals, Jacobi's elliptic functions, Jacobi's inverse elliptic functions, the Jacobi Zeta function and the Heuman Lambda function. The fundamental relations include identities, addition theorems and extension of the ranges of the argument and modulus of these functions. Also given are lists of special values, limiting values, differential equations satisfied by these functions, selected lists of conformal mapping properties and of transformation formulas. The typical form of each kind of function is illustrated by graphs.

Pages 42 to 190 contain extensive tables for reduction of the algebraic trigonometric and hyperbolic integrands of elliptic integrals encountered in practice to Jacobian elliptic functions. For every typical set of parameters, the appropriate substitutions are given, followed by lists of explicit expressions for special cases of the respective type. Each formula in these tables is followed by a reference to an entry in the table of integrals of Jacobian elliptic functions (pages 191 to 222) which forms the core of the handbook. The device adopted by the authors of first reducing the integrands to a standard form results not only in a great economy of space, but also in a logically very satisfactory arrangement of the material.

Pages 240 to 306 contain a miscellany of additional information relating to elliptic integrals of special types. Pages 249 to 251 contain a list of Laplace transforms containing elliptic integrals. Pages 252 to 271 refer to hyperelliptic integrals (whose integrand is of the general form $R[\tau, \sqrt{P(\tau)}]d\tau$, where R is a rational function of τ and $P(\tau)$ is a polynomial in τ with highest exponent greater than four) and their reduction to elliptic integrals in special cases of practical interest. Tables of integrals of elliptic integrals with respect to the argument or the modulus will be found on pages 272 to 281. Pages 282 to 306 contain formulas for derivatives with respect to argument, modulus or parameter (in elliptic integrals of the third kind) of the elliptic integrals and Jacobian elliptic and inverse elliptic functions; a collection of definite integrals of elliptic functions; and a table of series expansions of elliptic integrals and the associated functions.

An appendix (pages 307 to 321) deals briefly with the Weierstrass elliptic integrals and functions, and the Jacobi Theta functions as well as with "pseudo-elliptic" integrals which can be evaluated in terms of elementary functions.

Six-place tables of values of complete and incomplete elliptic integrals of the first and second kinds, of K times the Jacobi Zeta function, and of the Heuman Lambda function are given on pages 322 to 349. A bibliography of 39 references to books and tables and a general index complete this excellent work.

OTTO R. SPIES

ATOMIC AND FREE RADICAL REACTIONS, Vols. 1 & 2, by E. W. R. Steacie. Second edition, ACS Monograph No. 125, 901 pages, diagrams, 16 × 24 cm. New York, Reinhold Publishing Corp., 1954. Price, $28.00.

A scant half hour spent reading this scholarly second edition is sufficient to convince anyone of its timeliness. The bibliography contains 2086 references most of which have been published since the first edition appeared six years ago; apparently papers in this field

are appearing at a rate faster than one a day!

The book is concerned mainly with an outline of basic knowledge of elementary organic reactions in the gaseous state and in spite of this limitation, the title is justified since the fundamental laws will apply to all reactions. The serious recognition and study of organic free radicals commenced about the middle twenties of the present century with the work of H. S. Taylor, especially the part on the polymerization of ethylene by heating with small quantities of metal alkyls. The discovery of a means of detecting free methyl and other radicals by Paneth and Hofeditz was applied by F. O. Rice to organic thermal decompositions and finally in 1934 the qualitative description of products was placed on a quantitative basis by F. O. Rice and K. F. Herzfeld. This date marks the beginning of serious interest by the physical chemist in free radical mechanisms and the initiation of research programs in dozens of laboratories throughout the world.

Reactions between free radicals or between a free radical and a molecule differ from intermolecular reactions principally in their low activation energy and an immense amount of effort is now being directed to measuring this quantity for individual reactions. Here, fortunately, we can report large areas of substantial agreement in that measurements over a wide range of temperature by different methods have given reasonably consistent values for both A and E in the Arrhenius equation, $k = Ae^{-E/RT}$. There is now fairly general agreement, that the reaction between a radical and an organic molecule consists usually of the removal by the free radical of a hydrogen atom from the periphery of the molecule.

The agreement is not so general when one considers the thermal or photochemical decomposition of organic molecules. This may occur by rupture of a bond to give two free radicals or by formation of the products in a single elementary act. The effort now being put on this problem, especially through the use of the mass spectrometer and isotopically marked atoms will almost certainly settle the matter unequivocally in the not too distant future. Closely allied with this question is the measurement of bond strengths in organic molecules which gives us a minimum value for the activation energy of the primary decomposition into radicals. A considerable variety of methods are now available for measuring bond strengths and within moderate limits the agreement is satisfactory.

The method of presenting the huge unwieldy mass of data on elementary reactions has been to devote the first volume to a consideration of experimental methods, bond dissociation energies and free radical mechanisms of thermal and photochemical reactions.

The second volume is devoted to individual consideration of elementary reactions which are organized and numbered according to type. Almost one thousand reactions are considered, the principal types being systems containing carbon and hydrogen only, those containing carbon, hydrogen and oxygen, systems containing chloride and fluorine and systems involving reactions of sodium atoms with organic compounds usually with removal of a halogen.

A particularly valuable aspect of the second edition is that at the end of the second volume, in addition to the usual author and subject index there is included a bibliography of the work in this field and an index of bimolecular elementary reactions.

In this book, the reader will find a well organized, judicial and scholarly account of every phase of basic knowledge of free radical reactions.

F. O. RICE

PLASTICS ENGINEERING HANDBOOK, issued by The Society of the Plastics Industry, Inc. Second edition, 813 pages, diagrams, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1954. Price, $15.00.

This is a completely revised and greatly expanded version of the 1947 SPI *Handbook*. Nearly twice the size of the original handbook, this present volume contains completely new chapters—for example, Tooling with Plastics—as well as new information on material from the first edition. New in the present edition is the fold-out chart on adhesives in the chapter on Cementing and Assembly. The chart was compiled from data received from adhesives producers all over the country and is the most complete tabulation of its kind available. Anyone connected with the vast plastics industry will find this *Handbook* of inestimable value.

STEAM, AIR, AND GAS POWER, by William H. Severns, Howard E. Degler and John C. Miles. Fifth edition, 502 pages, diagrams, illustrations, 15 × 22 cm. New York, John Wiley & Sons, Inc., 1954. Price, $6.50.

Any book which runs into five editions has proved its worth. This new edition of a standard work on heat-power engineering covers essentially the same subjects as the prior editions—the construction, application and performance of modern steam, air and gas power plant equipment. New material includes a chapter on mechanical refrigeration, and the expansion of the sections on gas turbines, air compressors, and the combustion of oils and gases. New illustrations add to the usefulness of the book, and new, graded problems will aid both student and teacher. The present edition is completely up-to-date.

FARM BUILDINGS, by Deane G. Carter. Fourth edition, 291 pages, diagrams, illustrations, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1954. Price, $5.50.

The fourth edition of this well-known book has been drastically revised. Instead of giving detailed specifications (which are quickly outdated), the author attempts to guide the reader in solving his particular farm building problems through analysis with more general ones. Professor Carter covers farm buildings from the standpoints of building objectives, planning resources, functional aspects and environment. The discussion on production-management has been greatly expanded, and 90 per cent of the illustrations are new.

PRINCIPLES OF ENGINEERING THERMODYNAMICS, by Paul J. Kiefer, Gilbert F. Kinney and Milton C. Stuart. Second edition, 539 pages, diagrams, charts, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1954. Price, $7.75.

In 1930, the first edition of this standard text appeared. It has been used by a large number of teachers, whose recommendations for improvement have been incorporated into this second edition. The new material has been tested in mimeograph form in actual classes for several years at the U. S. Naval Postgraduate School, with good results. Emphasis continues to be on the principles of engineering thermodynamics. This new edition covers the thermodynamic basis of fluid mechanics and aerodynamics, unifying the mechanical, chemical and aerodynamic applications in an up-to-date way. The chemical background of the junior author, Gilbert Kinney, adds to the usefulness of this edition.

ELEMENTARY CHEMICAL ENGINEERING, by Max S. Peters. 322 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $6.00.

Aimed primarily at non-specialists with no previous training in the field, this text is intended to provide a general understanding of the practical science of chemical engineering. The text may also be used as an introductory course for chemical engineering majors. The essential purpose is to present a unified picture, with emphasis on the development, applications and interrelationships of the basic principles. A knowledge of calculus would be useful to the student, although in the sections where calculus is

used, simplified derivations are given for the benefit of those who are not familiar with the calculus.

TEN FOUNDING FATHERS OF THE ELECTRICAL SCIENCE, by Bern Dibner. 48 pages, portraits, illustrations, 21 × 27 cm. Norwalk (Conn.), Burndy Library, 1954. No price.

This elegantly printed compilation of biographies has been prepared to show the history of the development of the science of electricity. The ten "fathers" discussed are William Gilbert, Otto von Guericke, Benjamin Franklin, Alessandro Volta, Andre Marie Ampere, Georg Simon Ohm, Karl Friedrich Gauss, Michael Faraday, Joseph Henry and James Clerk Maxwell. A portrait of each man precedes an excellently written account of his contributions to electricity. Also, reproductions of the various instruments associated with each man give the reader a graphic idea of the simplicity of the experimental apparatus available to these men. The booklet has been presented to our Library by the author, and it is recommended reading for all who are interested in electricity, whether they be students or practicing electrical engineers.

"STROBE"—THE LIVELY LIGHT, by Howard Luray. Second edition, 144 pages, illustrations, 16 × 24 cm. San Francisco, Camera Craft Publishing Co., 1954. Price, $4.00.

Strobe is a manual on the use of the electronic flash for photography. The wide experience of the author as a photographer has permitted him to incorporate into this small volume all the salient information necessary to use successfully the electronic flash. He covers all the facets of this work and gives details which generally result from experience.

The editors wish to call to the attention of our readers the following books, published in 1954 by Dover Publications, New York. Only titles and prices are listed, since the works, all reprinted, are well known to those in the field. Dover Publications is performing a real service, especially to science students, through the republication of standard works in reasonably-priced editions.

THE GEOMETRY OF RENÉ DESCARTES. Translated from the French and Latin by David Eugene Smith and Marcia L. Latham, with a facsimile of the first edition, 1637. 244 pages, 14 × 21 cm. Price: $2.95 (cloth); $1.50 (paper).

SELECTED PAPERS ON NOISE & STOCHASTIC PROCESSES, edited by Nelson Wax. 337 pages, 16 × 24 cm. Price: $3.95 (cloth); $2.00 (paper). Collection of six papers by J. L. Doob, S. O. Rice, M. Kac, S. Chandrasekar, G. E. Uhlenbeck and L. S. Ornstein.

ELEMENTS OF NUMBER THEORY, by I. M. Vinogradov. Translated from the Fifth Revised Edition by Saul Kravetz. 227 pages, 14 × 21 cm. Price: $3.00 (cloth); $1.75 (paper).

THE DESIGN AND USE OF INSTRUMENTS AND ACCURATE MECHANISM, by T. N. Whitehead. 283 pages, 14 × 21 cm. Price: $3.50 (cloth); $1.95 (paper).

THE PSYCHOLOGY OF INVENTION IN THE MATHEMATICAL FIELD, by Jacques Hadamard. 145 pages, 14 × 21 cm. Price: $2.50 (cloth); $1.25 (paper).

GEOGRAPHICAL ESSAYS, by W. M. Davis. 777 pages, 15 × 22 cm. Unabridged reissue of a 45-year old classic, with an introductory note by Douglas Wilson Johnson. Price, $5.50 (cloth).

A TREATISE ON ELECTRICITY AND MAGNETISM, by James Clerk Maxwell. An unabridged republication of the last, Third Revised edition. Vols. I and II bound as one. 1082 pages, plates, 15 × 21 cm. Limited edition. Price, $4.95.

ON THE SENSATIONS OF TONE, by Hermann Helmholtz. Unabridged edition with a new introduction by Henry Margenau. 576 pages, 16 × 24 cm. Price, $4.95 (cloth).

New Fire Truck for the Army.—Even Arctic winds and desert dust won't bother Army firefighters if a new military fire truck passes the gruelling tests the Army Engineers are now giving it. Developed by the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Virginia, and the Walter Motor Truck Company of Long Island City, New York, it features a completely enclosed cab which is large enough to accommodate six fully-equipped men.

Climatic conditions won't have any telling effect on equipment. The entire unit is designed to operate efficiently in temperatures ranging from 65 deg. below zero to 125 deg. above. All equipment is enclosed in heated, insulated compartments. Heat is supplied by an automatic gasoline-fired electrically controlled coolant heater.

Powered by a 300-hp. rear engine, the truck is expected to negotiate rough terrain as well as some of the most mobile military wheeled vehicles now in use. It has four-wheel drive with self locking differentials, spring supported double reduction drives, and a three-speed transmission with torque converter. It also has an integral frame and a body constructed of lightweight aluminum. Twenty eight feet long and eight feet wide, it weighs approximately 31,000 lb. complete.

The truck carries a 750-gal. water tank and a 150-gal. foam tank. A pump, driven from the main engine can deliver 500 gal. of water a minute and 50 gal. of high pressure water fog a minute. Generating equipment is also provided for the foam.

The new truck should provide firefighters with a knockout punch which was sorely missing in fire vehicles used during World War II. Make-shift trucks consisting of fire equipment mounted on standard 1½-ton truck chassis were used in all theaters. They lacked mobility and very often were unable to reach fires. The trucks also carried inadequate 300-gal. water tanks and pumps of 300-gal.-per-minute capacity.

Near the end of the war, Army engineers developed a truck which overcame most of its predecessor's deficiencies. It was equipped with a larger tank and pump, but lacked power and speed and was not suitable for use in the Arctic. Winterization kits were developed, but these interfered with the operation of the fire fighting equipment and were difficult to install.

Simple Pre-Marking Method Devised for Testing Materials.—A thread is speeding the testing of material at the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Virginia. The brain child of Mr. Samuel Shapiro of the ERDL Materials Laboratory, the thread in a contrasting color is run through test fabrics during their manufacture to mark off the size of test samples. This makes it a simple matter to cut the material into the sizes required for weathering, fungus resistance, exposure or other tests run at the Laboratories on material under consideration for use in Engineer equipment. The pre-marking eliminates the time-consuming hand measuring and marking of the samples which previously had to be done by the project engineers.

Mr. Shapiro's method is also being used by Quartermaster and other government agencies and commercial firms engaged in material testing. A patent

application on the process has been filed.

"All-Transistor" Calculator.—An experimental "all-transistor" calculator with a computing unit about one-half the size and requiring only 5 per cent as much power as a comparable vacuum tube unit was demonstrated recently at International Business Machine's new Poughkeepsie, N. Y., research laboratory.

In presenting the calculator for its first public demonstration, W. W. McDowell, vice-president in charge of research and engineering, pointed out that it is an experimental machine. The new machine is comparable in capacity to IBM's type 604 electronic calculator, of which over 2000 are in use, it was said. The 604 uses 1250 vacuum tubes. While their speeds are similar, shown side by side the two machines provided a sharp contrast in size. This experimental engineering model is believed to be the first fully-operative transistorized computer complete with automatic input and output.

More than 2200 transistors are used in the machine. A number of these are of a design developed by the company's own engineers to meet the operating characteristics required in computer circuits.

In addition to reducing the size of the machine, transistors effect a 95 per cent reduction in the power requirements of the electronic unit, eliminating the need for a bulky power supply and forced air cooling of components.

Because transistors have a much longer life than vacuum tubes, IBM expects that the necessary maintenance of machines employing them will be significantly reduced from that of vacuum tube machines of today.

Printed wiring, replacing much of the wiring normally comprising a computer's nervous system, was incorporated into the design of the new calculator to simplify production and maintenance, and greatly reduce space requirements. The model contains 595 printed wiring panels, on which the transistors are mounted. Each panel is about two-thirds the size of an IBM card.

Two-Way Radio Helps Trucking Industry (*Automobile Facts*, Vol. XIII, No. 6).—A quiet revolution in city trucking operations has been under way for the past 18 months, with an assist from the Federal Communications Commission.

For many years, the FCC had banned the use of two-way radio by truckers in certain metropolitan areas, and forbade its use for pickup and delivery operations anywhere. Finally, a year ago last winter, it approved a new FM system developed by Motorola. Truckers rapidly installed the equipment in Chicago, Minneapolis, St. Paul, Ft. Wayne, Louisville and a host of other cities across the country. Results? Just short of phenomenal.

Efficiency, in terms of truck use and man-hours, shot up anywhere from 15 to 50 per cent. The average is probably around 25. A typical example explains why.

Ecko Products Company of Chicago got an order for special-sized baking pans, from Scranton Bakers' Supply Company in Scranton, Pa. Otto Richter, Ecko's assistant traffic manager, tells what happened:

"At 3:25, chief dispatcher Gordon Taylor of Eastern Motor Express took the incoming call from our shipping department and immediately cashed in on the breaks that only radio could give under the circumstances. He stopped truck 207, which was on the way back in, at Cicero and North Avenue, just minutes away from the

plant. Pickup was made by 3:35, 10 minutes after the order was placed."

Flexibility has been the strong suit of trucks from the very beginning. This latest of tools, putting the driver at all times within sound of the office, takes that flexibility a long step toward the ultimate.

"Somascope" Probes Body Secrets.—A device called the Somascope has been developed which is said to employ a combination of the principles of television, radar and sonar. It is used to look inside the human body to probe goiters, cysts, tumors, etc. in soft internal organs, in much the same way that X-rays show the bones and other such hard objects. Its developer, Dr. Douglass H. Howry of the University of Colorado Medical School, explains that the Somascope's sound waves throw back an echo from the soft tissue—the echo varying for different types of tissue—the echo in turn being transferred onto a TV-like screen as a picture, thus allowing surgeons to spot the diseased areas. Although the machine has not yet been perfected, it is the hope of Dr. Howry that it can be used to detect early cancers, as well as diseases of such organs as liver, pancreas, stomach, and intestines, which are now detected principally under exploratory surgery. He says that it can in some cases show the difference between tumors that are dangerous and those which are of no consequence.

Ultrasonic Fluxless Soldering.—Fluxless soldering is an important improvement in soldering techniques. It eliminates the need for a thorough washing to remove excess flux, and insures a joint free of contaminates often left by the flux. Fluxless soldering has been made practical by high powered ultrasonic equipment put on the market.

SONOBOND, developed by Aeroprojects, Inc., of West Chester, Pa., will tin aluminum, copper, magnesium and silver without the use of any flux. This equipment is being built with sufficient ultrasonic power to tin these metals readily on a production basis.

Aeroprojects' soldering shop has been using SONOBOND for a year and a half. Experimental or production orders of 1 to 10,000 parts are run in this pilot plant. In this way companies interested in the new process can prove its usefulness as a production method before the purchase of equipment. When a company is satisfied with the process, and production methods have been worked out, it can then procure the equipment best suited to its needs and install the operation in its own plant.

SONOBOND is simple to operate and requires no particular skill on the part of the operator. Aeroprojects' Pilot Plant operation demonstrates how simply jobs can be handled and how superior soldered joints can be made with fluxless soldering using SONOBOND.

Paper Strips Mark Road Repairs.—Paper strips cut from heavy roofing paper, painted with white traffic lacquer and sprinkled with glass beads were successfully used to route traffic around highway construction in California. Stuck to the road with asphaltic emulsion, made from petroleum, the strips can be taken up easily with a point shovel.

Collapsible Shipping Containers.—Granular materials, like dry chemicals, sugar and flour, soon may be shipped in ball-like containers that come in 2500-gal. sizes and are made of fabric and synthetic rubber, which is oil-derived. The eight-foot containers can be collapsed to two feet for storing and shipping.

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